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SIGNED MORE ESPECIALLY TO MEET THE REQUIREMENTS OF
THE INTERMEDIATE SCIENCE AND PRELIMINARY
SCIENTIFIC EXAMINATIONS OF THE
LONDON UNIVERSITY.

BY

J. R. AINSWORTH DAVIS, B.A.,
TRINITY COLLEGE, CAMBRIDGE;
LECTURER ON BIOLOGY IN THE UNIVERSITY COLLEGE OF WALES, ABERYSTWYTH.

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PREFACE.

DURING the last few years several excellent Text-Books of Practical Biology have been issued, following, in the main, the lines laid down in the well-known pioneer work of MM. Huxley and Martin. These have kept pace with recent research, and more than cover the enlarged Syllabus of Practical Work prescribed by the London University for the "Pass" Biology of its Intermediate and Preliminary Scientific Examinations. Up to the present time, however, no comprehensive work on Theoretical Biology, suited to the requirements of these and similar Examinations, has appeared, and self-taught Students have been compelled to seek the necessary information in numerous separate works and scattered Papers. The object of the present Text-Book is, therefore, to supply such a systematic and simple exposition of the subject within small compass as, it is hoped, will be found helpful, both to those who are studying alone, and to those who have the advantage of guidance in their work.

The Book is divided into two Parts, a Botanical and a Zoological, each of which deals with a number of Types morphologically and physiologically, then briefly draws out the points of comparison between them, and ends with an outline of Classification. A Bibliography, Index-Glossary, and set of Examination-Questions (most of which are reprinted, by kind permission, from the London University Calendars) are appended.

Many of the Illustrations are original, and have been prepared expressly for this Work; for permission to make use of others, I have to express my obligations to Professors Brefeld, Claus, Haddon, Prantl, Sachs, Sommer, Stirling, Strasburger, and Wiedersheim—as well as to the Rev. J. E. Vize, M.A.

My best thanks are also due to the Rev. W. L. Davidson, M.A., for kind assistance during the progress of the work; to Mr. J. W. Marshall, M.A., for valuable aid in the preparation of the Glossaries; and to my friend and draughtsman, Mr. H. W. Gilbert Williams, for the great care bestowed upon the execution of the original figures.

In conclusion, I may perhaps be allowed to say that I shall be glad to receive any corrections or suggestions for improvement.

J. R. A. D.

ABERYSTWYTH, *March*, 1888.

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A TEXT-BOOK OF BIOLOGY.

INTRODUCTION.

1. **BIOLOGY,** as the name implies, is the science of life. It deals, therefore, with living matter, which, at the outset, must be distinguished as clearly as possible from non-living matter. The points of difference may be conveniently grouped under four heads.

1. *Chemical Composition and Minute Structure.* — In all organisms life is associated with a semi-fluid, jelly-like substance, known as **Protoplasm.** This is characterized by its extremely complex chemical composition. Analysis shows the presence of *proteids* (composed of carbon, oxygen, hydrogen, and nitrogen, with small quantities of sulphur and phosphorus), and, to a less extent, of *carbohydrates* (substances allied to sugar and starch) and *fats,* which are both formed by the union of carbon, oxygen, and hydrogen. Each protoplasmic molecule is probably a union of simpler (though still very complex) molecules belonging to these three groups, the nitrogenous proteid part being, however, by far the most important. Living matter is extremely unstable, and this is, no doubt, largely due to the nitrogen invariably present in considerable quantities. Protoplasm always contains a large amount of water.

Regarding the ultimate structure of protoplasm, various theories have been propounded. One of the most plausible supposes its (chemical) molecules bound into an excessively fine and ever-varying network, the interstices of which are filled by water and other substances.

It has also been conceived of as made up of physical units (*micellæ, isotagmata,* &c.), separated by a water-layer of variable thickness. More recently, the theory has been propounded that protoplasm is an *emulsion—i.e.,* is made up of various substances mechanically suspended in fluid.

Only the very lowest organisms are formed *entirely* of protoplasm; other bodies, the results of its activity, are usually present.

2. *Outward Form.*—Organisms are invariably bounded by *curved* surfaces, and, except in the very simplest cases, possess a definite recognizable outward form. Non-living matter, on the contrary, is either *amorphous*, devoid of special form, or *crystalline*, when it is bounded by *plane* surfaces. The only constant elements connecting these are the angles formed by their junction.

Nevertheless, crystals (*e.g.*, diamond) do sometimes possess curved surfaces.

3. *Constant Local Death and Consequent Renewal.*—The chemical molecules of a mass of non-living matter may remain unaltered for an indefinite period. This is never the case with living matter. Its protoplasmic molecules are constantly breaking down into simpler compounds (waste-products, &c.) This process, which is essentially one of oxidation, may be termed *local death*. As the products of oxidation pass out of the body, a gradual diminution of size would take place, were not the loss repaired by *food*. If more food be taken in than that requisite to make up for waste, the result may be an increase of size known as *growth*. This, however, is limited in extent.

Both growth and repair of waste are effected by *intussusception*—that is, by the intercalation of new molecules between those already existing. The water permeating all parts of the organism renders this possible.

Non-living matter may exhibit a sort of growth. This is seen, for example, in crystals. Increase here, however, takes place by *accretion*—that is, new layers are added to the outside, the innermost layers being, therefore, the oldest. Moreover, this growth may be continued to any extent.

4. *Life-History.**—Any given organism passes through a definite series of changes, occupying a limited time, which collectively constitute its life-history. It is derived from a parent-organism, or organisms, carries on a number of operations, the

---

* This term has recently been extended by geologists to the sequence of changes undergone by some minerals, &c.

taking-in of food, &c., &c., and, after attaining a certain maximum size, dies and decays. In the course of its life, parts may become detached and grow into new individuals, extinction of the species being thus obviated.

Vital phenomena are strikingly dependent on certain conditions of moisture and temperature. As above-mentioned, protoplasm contains a large amount of water, the withdrawal of which cannot be effected beyond a certain point without destroying the molecular structure, and causing death. Desiccation suspends life-manifestations long before this point is reached.

As regards temperature, low forms can bear greater extremes than high ones. Protoplasm dies, undergoing "heat-stiffening" if raised to a temperature of, on the average, about 45° C., whilst vitality is arrested, but not necessarily destroyed, by freezing.

2. Connexion between Living and Non-Living Matter.—No links are known between living and non-living matter. It was, indeed, formerly held that organisms, even large ones, such as snakes and insects, could arise from non-living matter. Virgil's well-known recipe for obtaining bees is a case in point. This was the doctrine of *spontaneous generation* or *abiogenesis*. Accurate observations, however, gradually limited the belief to microscopic forms, and even these have now been proved to constitute no exception to the general rule, which, of course, is "life from life," or *biogenesis*. The latter doctrine, however, only covers known or ascertained facts, and obviously does not account for the first appearance of life upon the globe.

3. Subdivisions of Biology.—The "Science of Life" falls into two main subdivisions, **Botany** and **Zoology**, dealing with plants and animals respectively. These may both be regarded from two different points of view:—(1) The *morphological*, concerned with outward form and structure (inward form); (2) the *physiological*, treating of organisms in action, the various actions being known as *functions*. Thus we have, on the one hand, **Vegetable** and **Animal Morphology**; on the other, **Vegetable** and **Animal Physiology**.

The morphology of minute structure is termed **Histology**, while the morphology and physiology of young organisms, previous to their attaining the adult form, are known as **Development** or **Embryology**.

Distribution, in space and time, constitutes another important subdivision of biology, with which, however, we are not concerned within the limits of this text-book.

It must not be supposed that these branches of the subject are independent of one another. On the contrary, they are mutually implicated. A physiologist, for example, studying the action of the brain, must have a thorough knowledge of its structure. One of the most effective modes of bringing out this interdependence is the method of *comparison*. Hence we get **Comparative Morphology, Physiology,** &c.

4. Differences between Plants and Animals.—It might, at first sight, be imagined that no possible difficulty could be experienced in distinguishing between plants and animals. This is true as regards the higher forms, and the following table shows the most obvious differences :—

Higher Plants.	**Higher Animals.**
1. Power of Locomotion.	
Absent—*Exception* :—Spermatozoids of Ferns. These, however, are only *parts* of plants.	Present — *Exception* : — Adult Oyster, &c., but embryos of such forms are usually active.
2. Evident Sensitiveness.	
Absent — *Exception* :—Sensitive Plant. (Such sensitiveness is, however, very *local*.)	Present — *Exception* : — Hardly the case in Tapeworm.
3. Special Digestive Cavity. (*For Receiving Solid Food.*)	
Absent, food in solution, taken in by diffusion—*Exception* : — Pitcher plant. Possesses a kind of external stomach which digests solid food.	Present — *Exception* : — Tapeworm, which lives on food taken in by diffusion.

These tests, however, completely break down when applied to the lower forms of life. Locomotion is common amongst low plants (*Protococcus*), and sensitiveness seems as well developed in them as in low animals, which last are often devoid of any digestive cavity (*Amœba*). There are, on the other hand, two tests of more universal application, namely :—(1) The presence or absence of *cellulose* ; (2) the nature of the *food*.

(1.) The protoplasm of every undoubted plant forms, at one time or another, a protecting membranous substance, **Cellulose**

$[(C_6H_{10}O_5)_n]$, closely allied to starch. There are, however, stages in the life-history of many plants where cellulose is absent, and this substance is not absolutely confined to the vegetable kingdom, being present, for example, in the sea-squirts or ascidians.

(2.) The *nature of the food* is the most important distinction. Ordinary plants, by means of the green colouring-matter, **Chlorophyll**, which they contain, are able to utilize the kinetic energy of the sun's rays, converting it into potential energy by building up complex organic compounds from *simple* food, consisting of carbon dioxide, water, and simple salts containing sulphur, phosphorus, and nitrogen.

Animals, on the other hand, require *complex* food, their nitrogen being derived from ready-made proteids, and their carbon from compounds like fat, sugar, and starch. As these substances occur in the solid state, the necessity for a digestive cavity is obvious. It is absent in certain parasites, as the Tapeworm, where a solution has been prepared by another animal, and in forms like Amœba, where solid particles can readily pass into the soft protoplasm.

In applying this last test, difficulties are met with in both directions. A large number of plants, especially those known as *fungi*, are destitute of chlorophyll, and require complex food, although this sometimes shows a sort of half-way condition—ammonium tartrate, for example, serving the Yeast-Plant as a source of nitrogen. Even green plants, like the "insectivorous" plants—Pitcher-Plant, Sundew, &c.—partly live on ready-made proteids. On the other hand, some animals may develop chlorophyll, and thus partly follow the vegetable method of feeding. The green Hydra is a case in point.

It appears, then, that there is no absolute point of distinction, so far as we know, between plants and animals, and the balance of evidence must be taken in any particular case. It must also be remembered that difficulty is principally found when dealing with microscopic forms, where tests are difficult of application.

On this account, some naturalists have considered certain organisms half-plant and half-animal, whilst others (*e.g.*, *Haeckel*) have proposed the formation of an intermediate kingdom for the reception of doubtful forms.

5. Theory of Evolution.—It has just been seen that no sharp boundary-line can be drawn between plants and animals, and difficulty is again experienced when it is attempted to subdivide either the vegetable or the animal kingdom. Such facts as these, amongst very many others, led to the theory of **Evolution**, enunciated in its present form by Darwin and by Wallace. This theory, the key to Biology, binds together innumerable dry facts, often apparently quite isolated, and gives them a new and living interest. It regards all forms of life as having a common descent, a true blood-relationship, whence arises the impossibility of drawing hard and fast lines of separation. That diverse forms should arise from a common ancestor is thus explained. It is a matter of ordinary observation that an organism resembles, but never *exactly* resembles, its parent—that is, it *varies*. From this are deduced two laws—(1) *Law of Heredity*, according to which qualities are inherited; (2) *Law of Variation*, according to which new qualities arise.

Owing to overcrowding, there is ever a **struggle for existence** between organisms. Those which happen to vary in a favourable way will be most likely to succeed in the struggle, and produce offspring. This is "**survival of the fittest.**" Hence, from one form several different forms may arise, new characters being produced and exaggerated by Variation, Heredity rendering their preservation possible, and, so to speak, accumulating them.

An organism tends to inherit the characteristics, not only of its immediate progenitors, but of *all* its ancestors; the result of this being that, speaking generally, its development may be regarded as a compressed epitome of its pedigree. This explains a host of otherwise incomprehensible facts. In the embryo Rabbit, for example, there are at one period several slits, *visceral clefts*, placing the throat in communication with the exterior. These soon close up without performing any apparent function. It is known that, at the present time, Fishes possess such clefts in the adult condition, upon the edges of which gills are developed. Breathing is effected by the passage of water into the mouth, and through the clefts to the exterior. The conclusion may thence be drawn that the visceral clefts of the Rabbit are inherited from remote gill-possessing ancestors. The development of the Frog shows *how* a fish-like creature, possessing gills, can become an ambulatory animal breathing by lungs. Genealogies, imbedded in solid stone, exist in the geological record, and these, though much mutilated, prove that the higher forms of life *have* passed through simpler stages.

6. Classification.—Plants and animals are so exceedingly numerous that, in order to aid the memory, and throw meaning into an otherwise unintelligible mass of facts, it is necessary to classify them. Classification consists in two things—(1) The *formation* of groups, and (2) The *arrangement* of those groups when formed. In both cases, the principle of marking agreements and differences is adopted. In other words, the aim to be attained is the association of like organisms and like groups. The more characters that are taken into consideration, the more *natural* will be the classification, whereas a one-sided *artificial* arrangement will be produced by arbitrary selection for this purpose if one or a few characters only be taken at random. The popular classification of animals under the headings "biped" and "quadruped," is a case in point.

The smallest assemblage of forms is called a **Species**, which is made up of individuals differing from one another so little that they are immediately recognized as belonging to one "kind." Sex, of course, is not a specific character. Species are again grouped on the same principles into **Genera**, and genera into still larger groups, and so on. At each step it is obvious that the number of common characters must diminish, as a larger number of organisms exhibiting greater dissimilarity is taken in. It is ultimately found that comparatively few large groups are formed. The **definition** of any group is the enumeration of those characters possessed by the various members of the group by which they are marked off from the members of other groups of the same rank.

Evolutionally conceived, the arrangement of groups is the endeavour to express the **blood-relationship** existing between organisms. As a result, a tree-like arrangement (not a straight line or *linear series*) is produced, in which the main divisions of the trunk represent the largest groups, the ultimate twigs the species (and leaves the individuals), and the intermediate boughs and branches the other sub-divisions. From the evolutionary point of view, this tree is a genealogical one, and as in Nature particular tree-branches are not at all points sharply marked off from other branches, so in classification particular groups are not sharply separated at all points from other groups.

In other words, the definition of any group does not absolutely apply in every respect to each member of the group, and the balance of characters must be taken.

In the following chapters a number of **types**—*i.e.*, fair average examples—of the more important groups are described. The salient characteristics of those types are then briefly dealt with from a comparative point of view, and classification is succinctly treated on this basis.

It may here be stated that organisms are named bi-nomially for scientific convenience. The first name is the Genus and the second the Species, *e.g.*, *Protococcus pluvialis.*

PART I.

VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

CHAPTER I.—FUNGI.

§ 1. SACCHAROMYCES (The Yeast-Plant).

Alcoholic fermentation, in which alcohol is produced by the splitting-up of sugar, results from the presence of vast numbers of Yeast-plants. These may be found either at the top or bottom of fermenting solutions, as "top" or "bottom" yeast respectively.

MORPHOLOGY.

In the case of "bottom" yeast, each plant is a minute sphere (Fig. 1—1), about $\frac{1}{3000}$ of an inch in diameter, and hence requiring a high power of the microscope to make out its characters. Those of "top" yeast possess an ellipsoidal form, but are of proportionate dimensions. The Yeast-plants are found aggregated loosely together into groups of various shapes and sizes (Fig. 1—2 and 3). This is the result of **budding**, by which process multiplication is mainly effected. Each individual is a single **cell**, or morphological unit. This is the simplest case of plant-structure. The yeast-cell, however, is not homogeneous, parts of different natures may be discerned in it. The exterior is covered by a delicate, transparent, elastic membrane, the *cell-wall*, which is composed of cellulose. Within this a granular

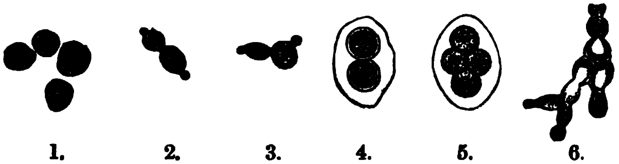

Fig. 1.—Saccharomyces (The Yeast-Plant) strongly magnified (from *Landois and Stirling*).—1, Isolated Yeast-plants; 2, 3, Gemmation; 4, 5, Formation of Endogonidia; 6, Budding of Endogonidia.

colourless mass, the *protoplasm*, is present, which contains, as a rule, a large clear space, the *vacuole*, filled with fluid (Fig. 1—6). Much smaller vacuoles may also occur (Fig. 1—1). A more solid particle, the *nucleus*, is said to occur in some specimens.

PHYSIOLOGY.

Certain functions are carried on by the Yeast-plant, which may be considered under four headings.

1. **Nutrition.**—In order that waste, which is continually going on (*see below*) in the protoplasm, may be counterbalanced, certain substances, collectively constituting the *food*, must be taken in from the outside. It is essential that these should be in a state of *solution*, when they can readily be absorbed—that is, diffuse through the cell-wall into the protoplasm. *Pasteur's solution*—composed of potassium and calcium phosphates, magnesium sulphate, and ammonium tartrate, dissolved in a relatively large bulk of water—will serve as food.

It will be observed that Pasteur's solution contains carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, and magnesium. These are *essential* elements in the food of *all* plants, the first six because they are components of protoplasm, &c. (*compare p.* 1), the others because they exert a beneficial influence on various processes.

Organic substances, *e.g.*, ammonium tartrate, must be among the food-constituents of yeast and other colourless plants. Absorption is followed by *assimilation;* in other words, the comparatively simple molecules of the food are built up into more complex molecules and ultimately into protoplasm. This last is the *essential* part of the cell, and all the functions of life are performed by it. The cell-wall appears to be formed by the transformation of a thin surface-layer of protoplasm.

The Yeast-plant can utilize proteid solutions as sources of nitrogen, thus approaching the animal mode of nutrition (*compare p.* 5). Its life is most vigorous when sugar is contained in the surrounding solution. This, influenced by the cell-protoplasm in some way not understood, *ferments*—that is, breaks up into simpler substances, mainly alcohol and carbon dioxide. This process is, for some unexplained reason, beneficial to the yeast.

If more food is used than is necessary to make up for waste, *growth* and *reproduction* may ensue, within certain limits.

2. **Destructive Metabolism.**—The complex protoplasmic molecules are constantly breaking down into simpler substances, some of which, *waste products*, are of no use to the plant, and are (in part) *excreted*, or passed out to the exterior. That such waste actually takes place, may be demonstrated by placing Yeast-plants in distilled water, when they decrease in size, and ultimately die. The kinetic energy necessary for the performance of vital functions is gained by this process of breaking-down, or destructive metabolism. When yeast is causing fermentation (and this is its most healthy state), *free oxygen is not necessary*, and indeed arrests the process. Under other circumstances, yeast appears to do what all other organisms (except Bacteria) *always* do—that is, *respire*.

Respiration consists in getting rid of carbon dioxide (one waste product), *free oxygen* being at the same time absorbed. The necessity for free oxygen lies in the fact that destructive metabolism is essentially a process of *oxidation*.

It has been supposed that the oxygen enters into the composition of the protoplasm molecules, rendering them unstable, with the result that breaking-down into simpler products follows sooner or later.

In Yeast (and Bacteria) *fermentation* seems to obviate, somehow or other, the necessity for respiration.

3. **Reproduction.**—The Yeast-plant has only a limited term of life, and would soon become extinct were it not able to reproduce its kind. This is usually effected by budding or **gemmation**, which proceeds vigorously under favourable circumstances. Small projections grow out from the parent-cell (Fig. 1—2 and 3), and gradually attain the same size, being at the same time narrowed off, and ultimately separated. Several generations of buds may cling together, and this accounts for their occurrence in groups, as already mentioned. This is a form of **vegetative** reproduction, *i.e.*, no *special* reproductive cells are formed (*compare p.* 18).

If the food-supply is limited or cut off, as, for example, when the plant is cultivated on a plaster-of-Paris surface, reproduction may be effected in a, so to speak, more economical way. The protoplasm divides up into four parts (Fig. 1—5), which form cell-walls, and are termed **Endogonidia.** If placed in a nutritive medium, these can multiply by budding (Fig. 1—6), the cell-wall of the parent-plant being cast off. This is a form of **asexual** reproduction (*see p.* 18).

§ 2. BACTERIA.

Bacteria are excessively minute organisms everywhere present in the air, causing putrefaction, and probably many diseases, such as cholera and consumption. They are so small that, even with high powers of the microscope, their structure is difficult to make out.

MORPHOLOGY.

The **form** of Bacteria presents considerable variations, and upon this the genera* are principally founded. The following are among the most important (Fig 2):—

(1.) *Micrococcus* (Fig. 2, A) made up of small rounded cells which may be separated, or united together into small groups.

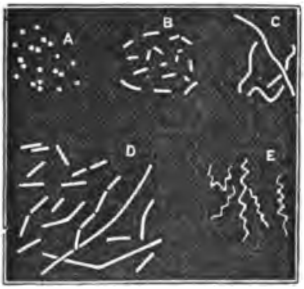

Fig. 2.—Bacteria, very much magnified (from *Landois and Stirling*).—A, Micrococcus; B, Bacterium; D, Bacillus; E, Spirillum.

(2.) *Bacterium* (Fig. 2, B) differs from the preceding only in being shortly cylindrical.

(3.) *Bacillus* (Fig. 2, D) slender rods.

(4.) *Spirillum* (Fig. 2, E)—elongated, spirally-coiled filaments.

In all cases, they are composed of colourless protoplasm, covered by a very delicate cellulose membrane. In Bacillus and Spirillum a delicate protoplasmic filament or *flagellum* (Fig. 3—10) is present at either end, and they are consequently motile. These "swarming" forms pass, however, into a quiescent stage, known as the *Zooglœa stage*, in which they are imbedded in a gelatinous substance secreted by them, and form a kind of scum upon the surface of putrefying solutions, &c.

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* These in many cases appear to be merely *stages* in the life-history of one and the same form.

PHYSIOLOGY.

1. **Nutrition** is very similar to that of the Yeast-plant (p. 12); but in this case *putrefactive,* instead of *alcoholic,* fermentation is associated with it.

2. **Destructive Metabolism.**—Compare the account of this in Yeast (p. 13). Free oxygen does not appear to be requisite in many cases, and its presence is detrimental to putrefaction.

3. **Reproduction.**—This may be either vegetative or asexual:—

(*a.*) **Vegetative Reproduction** is effected by splitting or *fission,* as, for example, in Bacillus (Fig. 1, D).

(*b.*) **Asexual Reproduction** leads to the formation of excessively minute *spores.* In *Bacillus subtilis* (the Hay-Bacillus), for example, the protoplasm in each rod (Fig. 3—8 and 9) contracts, and forms an extremely small oval spore, which can again germinate, as shown in Fig. 3—2, 4. Or a thread may be formed (Fig. 2—7) in the cells of which spores arise. The spores develop when the organic substances in which the Bacilli are living become exhausted; and when these are dried up, they are carried away by air-currents to other favourable localities. Spores are formed in many other Bacteria—*e.g.*, *Spirillum.*

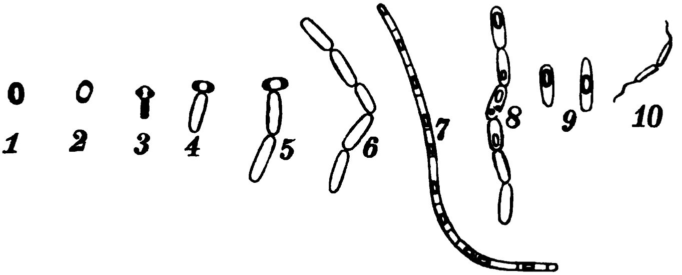

Fig. 3.—BACILLUS SUBTILIS (THE HAY-BACILLUS), immensely enlarged [from *Landois and Stirling*].—1, Spore; 2, 3, 4, germination of spore; 5, 6, chains of bacilli; 7, thread with spores; 8, chain with spores; 9, isolated examples with spores; 10, two examples with flagella.

4. **Contractility** is exhibited in the movements of the "swarming" forms (*compare p.* 26).

After *spontaneous generation* (*see p.* 3) had been conclusively disproved for higher organisms, it was still believed by many to hold good in the case of Bacteria, the spores of which, everywhere present in the air, were overlooked. An infusion of hay, for example, if left exposed, will rapidly putrefy, and in it Bacteria will be found in vast numbers. But if, when the infusion is boiling, and steam issuing from the vessel in which it is contained, the mouth of the vessel is closed with a plug of cotton-wool, the liquid will remain clear and free from Bacteria for an indefinite time, for all germs within are destroyed by the boiling, and the intricate arrangement of the cotton fibres prevents others from entering. Putrefaction and concomitant Bacteria quickly appear, however, as before, if the plug is removed. Experiments like this have quite dislodged "abiogenesis" from its last foothold; but it must be carefully remembered that this does not prove it *never* to have occurred (*compare p.* 3).

§ 3. MUCOR MUCEDO (White Mould).

This is a low plant found growing on various substances—bread, apples, horse-dung, &c.—which have been kept for some time in a moist, warm atmosphere.

MORPHOLOGY.

1. **Vegetative Organs.***—The plant-body, or *mycelium*, is made up of delicate, branching, white filaments, *hyphæ*. Innumerable plants are interwoven together to form a loose cottony mass upon the substratum. A young Mucor is a much-branched tube, the ramifications of which radiate from a central point in a star-like manner (Fig. 4, B). Before reproductive organs are developed, it may be regarded as a single cell, since the granular protoplasm filling the hyphæ within their delicate cellulose walls is everywhere quite continuous, partition-walls, septa, being absent. Vacuoles are present in the protoplasm, which also contains a large number of small *nuclei*—that is, denser particles, differentiated within it.

2. **Reproductive Organs.**—These are of two kinds—*asexual* and *sexual* (*see p.* 18).

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* This collective name is conveniently given to those organs which perform functions other than that of reproduction.

(*a.*) The **asexual reproductive organs** are globular cells—*sporangia* (Fig. 4, *sp*), placed on the ends of upwardly-directed *gonidiophores* (Fig. 4, *g*). These are special branches of the mycelium which grow up into the air till they attain their full length (about 2 inches). The end of each then swells into a small round knob, the *sporangium*. This is shut off from the hypha by a partition-wall that is extremely convex towards the sporangium, and bulging into its cavity constitutes the *columella* (Fig. 4, *c*). The wall of the sporangium (Fig. 4, *w*) is covered by a crust of oxalate of lime, studded with numerous minute projections. The protoplasm contained in the sporangium divides into a large number of cylindrical *endogonidia* (Fig. 4, *e-g*), which, when ripe, possess cellulose coatings of their own. They are separated by a jelly-like intermediate substance. After the

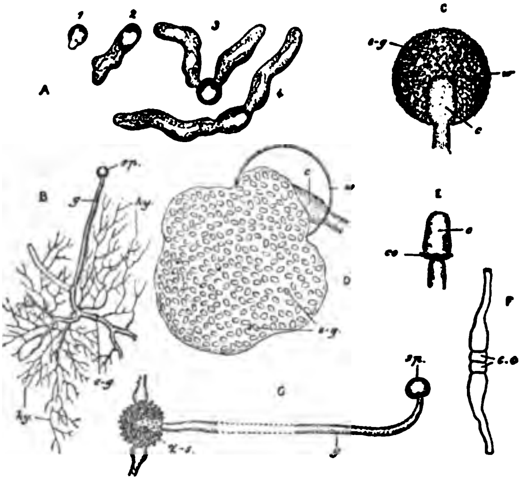

Fig. 4.—Mucor mucedo, variously enlarged (after *Brefeld*).—A, 1-4, stages in development of endogonidia; B, a young plant with a single gonidiophore (*g*) bearing a sporangium; *hy*, much-branched hyphæ (many omitted); C, mature sporangium; D, burst sporangium; E, do., endogonidia gone; F, conjugating branches; G, pro-mycelium, slightly modified and reduced in length; *c*, columella; *c.c*, conjugating cells; *co*, collar; *e-g*, endogonidia; *g*, gonidiophore; *hy*, hyphæ; *sp*, sporangium; *w*, wall of sporangium; *z-s*, zygospore, dark outer, and light middle coats ruptured.

rupture of the sporangium and escape of its contents (Fig. 4, D), the gonidiophore remains for a time with the columella at its end (Fig. 4, E), and the remains of the sporangial wall around its base constitute the so-called *collar.*

(*b.*) **The sexual reproductive organs,** which occur more rarely, are special short branches of the general mycelium, the ends of which are cut off by septa as sexual cells or **gametes** (Fig. 4, F, *c.c*). These organs arise in pairs, the two in each pair, quite similar to all appearance (although one may be a little smaller than the other), growing towards each other from adjoining hyphæ.

PHYSIOLOGY.

1. **Nutrition.**—The food is similar to that of the Yeast-plant (p. 12), and the organic part of it is derived from dead animal or vegetable substances. Under abnormal circumstances, Mucor may give rise to alcoholic fermentation in a sugar-solution. If submerged in such a solution, it breaks up into short lengths, which bud like Yeast, and thus come to assume a similar form. This *Mucor-yeast* causes fermentation.

2. **Destructive Metabolism.**—Under ordinary circumstances true **respiration** (*compare p.* 13) takes place, but a very small amount of free oxygen will suffice, and Mucor-yeast can dispense with it altogether.

3. **Reproduction.**—Three methods may be distinguished, viz.:—*Vegetative, Asexual, and Sexual.*

(*a.*) **Vegetative Reproduction** is effected by the separation of parts of the general plant-body often without special modification. Under unfavourable circumstances, short lengths of the hyphæ are often marked off by septa, and become oval *gemmæ.* These can develop into new plants, if placed under favourable conditions.

(*b.*) In both **asexual** and **sexual reproduction,** specially modified reproductive cells, known as **spores,** are produced. But in the former case, of which the endogonidia furnish an example, these cells are developed from the protoplasm of a *single* organ, while in the latter case, a spore is formed by the union of protoplasm from *two* distinct organs. The *sporangium* of Mucor, producing, as it does, reproductive cells without the co-operation of other structures, is an **asexual reproductive organ.** On the other hand, the special short branches described above are **sexual reproductive organs.** They meet each other; the cell-walls are absorbed at the point of contact, and the protoplasm at their ends fuses to produce a reproductive cell, the *zygospore*[*] (Fig. 4, G, *z-s*). This simple type of sexual reproduction, where the uniting elements are quite similar, is known as **conjugation.** The ripe zygospore (Fig. 4, G) is a minute, rounded, black body, which often becomes detached. It possesses three coatings, the outermost of which, formed from the cell-walls of the fusing masses of protoplasm, is dark and thick, with an irregular surface raised into hollow projections. Within this are the two coatings of the spore proper, the outer of which, *exospore,* is thickened but pale in colour. It possesses prominences which fit into the hollow projections of the outermost investment. Within the exospore is a delicate, thin *endospore.*

DEVELOPMENT.

The wall of the ripe sporangium consists of little more than a thin crust of calcium oxalate, the other part having been absorbed, and is, therefore, easily ruptured, its contents flowing out (Fig. 4, D). This process is effected by the intermediate substance, which swells up by absorption of water. The **endogonidia,** placed under favourable conditions (Fig. 4, A), at once begin to develop. They first swell up, and then hyphæ grow out in different directions, the endogonidium forming the centre of the young mycelium. Ultimately an adult Mucor-plant is formed, which gives rise to one or more sporangia, and then dies.

The **zygospore** remains dormant for five or six weeks, and then the dark coating and exospore are ruptured, while the protoplasm covered by the endospore grows out into a *gonidiophore* terminating in a sporangium (Fig. 4, G). Development proceeds no further. The endogonidia of this dwarf-plant or **promycelium** differ in no way from the ordinary ones. Here is a case of *alternation of generations,* or succession of sexual and asexual stages in the life-history of the same form. The ordinary Mucor-plant can produce sexual organs, and may be termed the **sexual generation** or **oophyte**, while the promycelium *never* produces sexual organs, and may be termed the **asexual generation** or **sporophyte**. If these are indicated by S and A respectively, the life-cycle may be written A—S. Owing to the power possessed by the sexual generation of producing new generations like itself *asexually*, and also to the comparative rarity of sexual organs, the alternation is ill-marked.

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[*] It is convenient to express special characteristics of certain spores by prefixes. *Zygo*, *e.g.* (ζεύγνυμι, to unite), indicates that the spore has been formed by union of two similar elements.

§ 4. PENICILLIUM GLAUCUM (Green Mould).

This is one of the commonest of the lower plants, and is found growing on the most diverse substances, food and old leather being perhaps the most readily attacked.

MORPHOLOGY.

1. **Vegetative Organs.**—Immense numbers of plants grow with their mycelia inextricably matted together, forming when mature a thick greenish crust, which, if still extending, possesses a white margin, for the young plants are white in colour.

The *mycelium* is composed of very numerous much-branched **hyphæ**, which are a great deal smaller than those of Mucor. The branches are of the same size as the main hyphæ. From the under-surface of the mycelium, a considerable number of branches grow downwards into the substratum. These are termed *submerged hyphæ*. Numerous partition-walls occur, dividing the plant into cells, not usually of great length (Fig. 5). Their walls are of cellulose, and they contain colourless granular protoplasm with numerous minute vacuoles, and several minute *nuclei*. The branches are of two kinds—(1) those given off from the growing ends of hyphæ (these increasing by *apical growth*), and (2) those growing out from ordinary cells. As a hypha increases in length, septa are formed in *acropetal* succession—that is, the youngest are nearest the growing point—*behind* which branches may grow out from the cells thus marked off.

2. **Reproductive Organs.**—Both *asexual* and *sexual* organs may occur.

(*a.*) **Asexual Reproductive Organs.**—Any of the ordinary hyphæ are capable of raising themselves into the air and becoming *gonidiophores.* These may be more or less branched (according to state of nutrition), to form a brush-like structure. The branches and main hypha, instead of growing indefinitely in length, terminate in short cells, the ends of which alternately swell up, and are constricted to form chains of spherical *stylogonidia,* which are broken up by the slightest touch (Fig. 5, C). The ripe stylogonidia are of a sage-green colour, and it is their presence which gives to Penicillium its characteristic hue.

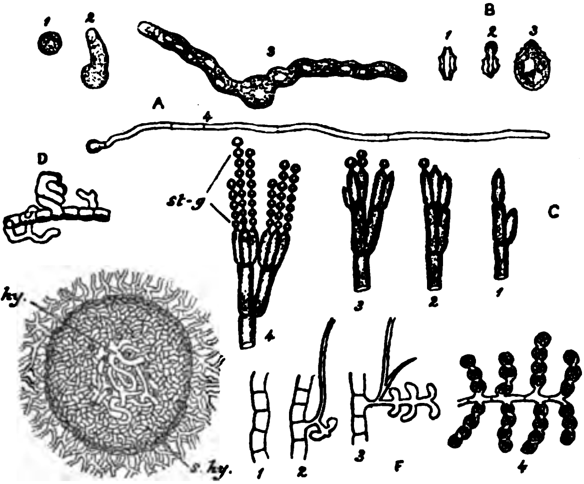

Fig. 5.—Penicillium Glaucum (after *Brefeld,* F, diagrammatized), enlarged variously.—A, 1-4, Development of stylogonidia; 4, less enlarged than the others. B, 1-3, Early stages in development of an ascospore. C, 1-4, Development of a gonidiophore; *st-g.,* stylogonidia. D, Reproductive organs, the surrounding hyphæ just commencing to grow up round them. E, Section of young fruit; *s.hy.,* sterile hyphæ; *f.hy.,* fertile hyphæ. F, 1-4, Diagram of development of asci; 1, part of fertile hypha divided into cells; 2, out-growth of nutritive filament with ascogenous protuberance at its base; 3 and 4, further development of latter.

(*b.*) **Sexual Reproductive Organs.**—These are only formed under exceptional circumstances (*see p.* 22), and have, as yet, only been obtained artificially. Two short spirally-coiled tubes grow out from adjacent cells of the same hypha, and twine closely together (Fig. 5, D). These are similar in appearance;

but, from analogy with other forms, one is considered as a male, the other as a female organ, and they are termed respectively *antheridium* and *carpogonium* (or *archicarp*). As in Mucor, an *alternation of generations* is present. The *sexual* generation, which, however, but rarely reproduces sexually, has been just described; the *asexual* generation (= promycelium of Mucor) is insignificant and will be dealt with under Development.

PHYSIOLOGY.

1. **Nutrition** is exactly comparable to that of Mucor. The submerged hyphæ have, no doubt, as their especial function the extraction of nutriment from the substratum. Penicillium-yeast can be produced like Mucor-yeast (*see p.* 18).

2. **Destructive Metabolism.**—As in Mucor, respiration is, however, much more vigorous.

3. **Reproduction.**—(*a.*) The **asexual reproduction** does not involve, as in Mucor, the death of all or part of the mycelium of the sexual generation. Moreover, the asexual reproductive organs are less highly specialized.

(*b.*) **Sexual reproduction** only appears when the supply of free oxygen is limited, and the excessive development of asexual organs thereby prevented. As in Mucor, the protoplasm of the two organs fuses. Judging from the analogy of other plants, the contents of the antheridium pass over into the carpogonium, which remains passive. Such a passage from a male to a female organ is termed **fertilization**, and characterizes true sexual reproduction as distinguished from conjugation.

DEVELOPMENT.

The **stylogonidia** can at once develop in somewhat the same manner as the *endogonidia* of Mucor. They are, however, very much smaller, and the hyphæ that grow out from them are relatively narrow, and soon begin to form the characteristic septa (Fig. 5, A).

After fertilization, the antheridium (presumably) withers away; but the fertilized carpogonium commences active growth, branches considerably, and becomes closely encompassed by numerous interwoven hyphæ from the surrounding mycelium. The two elements ultimately develop into a rounded "*fruit*," about the size of a small pin's-head. Of this, the branched structure developed from the carpogonium, which must be regarded as the rudimentary asexual generation, constitutes the *fertile* part, while the surrounding hyphæ form a closely compacted *sterile* part (Fig. 5, E). The branches of the asexual generation become divided into numerous cells by transverse septa (Fig. 5, F). From these cells there grow out—(1) Thin *nutritive* filaments, and projecting from the bases of these; (2) thick *ascogenous* protuberances. The first branch considerably, and penetrating into the surrounding sterile part of the fruit, obtain nutriment for the second. Each of these elongates and forms numerous pairs of thick branches, which become divided into oval cases, the *asci*. The protoplasm within each ascus divides into eight small masses, the *ascospores*. The ripe fruit, which takes some six or eight months to form, is of a bright orange colour, and consists of a thin outer wall, within which are innumerable ascospores of the same tint. These possess a delicate *endospore* and a thickened *exospore*. They can remain dormant for some time. Germination is similar to that of the stylogonidia, and is initiated by splitting of the exospore into two halves (Fig. 5, B).

CHAPTER II.—ALGÆ.

§ 5. PROTOCOCCUS (Hæmatococcus) PLUVIALIS.

Large numbers of this minute plant occur together, and form green or reddish incrustations in damp places. In the "motile" stage it is found swimming freely in stagnant water, especially in puddles of rain-water.

MORPHOLOGY.

In the *stationary* stage (Fig. 6, A), Protococcus is a minute sphere about $\frac{1}{500}$ of an inch in diameter, coloured green, red, or a mixture of the two. A firm, transparent *cell-wall* (*c.w*), composed of cellulose, surrounds the granular *protoplasm* (*pm*), which may possess vacuoles, and in which a *nucleus* is present. A green colouring-matter, *chlorophyll*, is distributed through most of the protoplasm, though it may be more or less obscured by the presence of red pigment. It is contained in a number of superficial overlapping *chromatophores*.

Free-swimming examples in the *motile* stage are often met with. These *zoospores* (Fig. 6, E) consist of a pear-shaped mass of protoplasm, through almost all of which chlorophyll is diffused. Near the narrow end is a red spot, and the extreme apex is occupied by a clear area, to which are attached two long, delicate filaments of protoplasm, the *flagella* (*f*). The smaller ones possess no further structure, but the larger ones may be surrounded by a delicate cell-wall (*c.w*), which, being at a little distance from them, looks like a transparent bladder. The cell-wall is perforated by the flagella, and besides these delicate protoplasmic strands may run from it to the protoplasm.

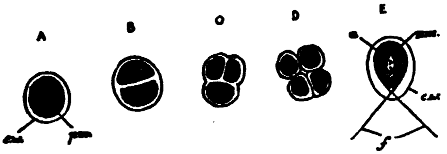

Fig. 6.—PROTOCOCCUS PLUVIALIS.—A-D, Stages in fission; E, zoospore; *c.w*, cell-wall; *pm*, protoplasm; *n*, nucleus; *f*, flagella, arising from clear part of protoplasm and piercing cell-wall.

PHYSIOLOGY.

1. Nutrition.—The food, as in all plants coloured green by chlorophyll (there is none in Penicillium), is simpler than that required by Yeast, Mucor, and other forms devoid of chlorophyll. These are sometimes termed "colourless," the others "green" plants, names having sole reference to the absence or presence of chlorophyll.

In addition to the elements required by Yeast, &c. (*see p.* 12), Iron is requisite. The food consists—(1) of *carbon dioxide*, which is dissolved in the surrounding water, and has been derived from the air. Chlorophyll is able (*see p.* 15), *in the presence of sunlight*, to decompose this into its constituents, the carbon being utilized while the oxygen is liberated. The oxygen thus set free by green plants is popularly, but very erroneously, believed to be given out as a result of "breathing," or respiration. (2) The elements other than carbon are absorbed in the form of water, and inorganic salts in a state of solution.

Rain, in falling through the air, becomes sufficiently impregnated with carbon dioxide and simple salts (present in the *dust* which abounds in the atmosphere), to serve as a medium wherein Protococcus can thrive.

The simple food is not at once transformed into protoplasm or cellulose. Several intervening steps must be passed through, and intermediate *plastic products* formed. One of the most important of these is *starch*, only produced in the presence of chlorophyll. Strange as it may seem, this is not formed *directly*, but *indirectly*, by the breaking down of protoplasm. The stages between the food and the protoplasm may best be shown by a table, which will, at the same time, serve to illustrate the characteristic nutritional differences between green plants, colourless plants, and animals.

STAGE 1.	STAGE 2.	STAGE 3.
Green Plants only.	**Green and Colourless Plants.**	**Green Plants, Colourless Plants, and Animals.**
By Chlorophyll.	*Independently of Chlorophyll.*	
Non-nitrogenous organic substance. (Carbon, hydrogen, and oxygen.)	*Nitrogenous organic* substance culminating in *proteid*. (Carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus.)	*Protoplasm.*
Formed from		
Carbon dioxide and water. Oxygen from former set free. (At same time *starch*, a non-nitr. org. substance, formed by decomposition of protoplasm.)	*Non-nitrogenous organic* substance (including *starch* in green plants) and *inorganic salts.*	*Proteids* and *non-nitrogenous organic* substance.

(*For exceptions to the above, compare p. 5.*)

2. **Destructive Metabolism.**—Under *all* circumstances **respiration** goes on, but in sunlight it is much obscured by the evolution of oxygen as a result of nutrition.

3. **Reproduction.**—Both vegetative and asexual modes occur.

(*a.*) **Vegetative.**—In the stationary stage, which must be considered as the normal *adult* condition, this is effected by a process of splitting, or *fission* (Fig. 6, B-D). A cell-wall is formed, which runs across the plant and divides it into two halves. This is followed by another at right angles, and the quadrants gradually separate, and round themselves off as new individuals.

(*b.*) **Asexual.**—The protoplasm of a plant divides into a variable number of parts, which, by the rupture of the cell-wall, escape as *zoospores*. These are at first destitute of investment, but sooner or later develop cell-walls, and ultimately settle down and become "stationary."

4. **Contractility.**—This is a property possessed by the zoospores. The protoplasm of the flagella contracts—*i.e.*, shortens in one direction with corresponding increase in another, so as to produce alternate bending and straightening in different parts of these organs. The lashing movements thus produced subserve locomotion, the flagellate end being in front.

Note that contractility does *not* involve diminution in *volume*.

5. **Irritability and Spontaneity.**—The movements of the zoospores are influenced by external influences or *stimuli*. Such a stimulus is found in light, which either attracts or repels them. This is a case of "irritability." But the contractions of the flagella are so persistent under all sorts of conditions that they are evidently the result for the most part of *internal* stimuli, and are hence said to be "spontaneous."

The last two functions—*i.e.*, contractility, and irritability and spontaneity—are most markedly present in animals. They have, therefore, been termed "animal," in contradistinction to the remaining or "vegetable" functions.

§ 6. SPIROGYRA.

A plant usually found floating in pools of fresh water, and aggregated with others to form bright green tufts. There are many kinds.

MORPHOLOGY.

Spirogyra differs from Protococcus in that it is (usually) multicellular. The plant-body is a cylindrical filament of varying length, formed by a number of cells placed end to end, and hence termed a *cell-row*. The thickness varies according to the species. Viewed with the naked eye, the plants present the appearance of excessively fine green hairs. All the constituent cells are similar in structure, but the end cells are rounded off. They vary in length according to the species; but, even in the same plant, no great constancy is exhibited. Usually, however, their length is considerably greater than their breadth.

Each cell (Fig 7) is of cylindrical form, and is separated from its neighbours by thin, slightly curved cellulose septa. The outer wall is also of cellulose, and consists of an inner thicker layer, outside of which is a thin, much less evident pellicle, which forms part of a delicate common investment to the filament. The outer wall (together with the septa) makes up the *cell-wall;* but, as in the hyphæ of Penicillium, part of this is *common* to the adjoining cells. By transparency the interior of the cell is well seen; its wall is lined by a thin layer of protoplasm, the *primordial utricle.* This is colourless with the exception of a spiral * *chlorophyll band,* which forms part of it. This winds round and round the cell, usually in a transverse direction, varying in thickness and in the number and obliquity of turns according to circumstances. Its characters are important for the determination of species. In a healthy plant, the edges of the band are jagged, and it contains a row of small spheres, the *chlorophyll corpuscles,* running down its centre. These are often closely invested by minute granules of starch. Within the primordial utricle the cell is principally occupied by a large *vacuole,* filled with *cell-sap.* In the centre of this a small mass of protoplasm is slung by fine protoplasmic threads, which connect it with the utricle. A spherical or lenticular *nucleus,* containing usually a denser particle, the *nucleolus* (and sometimes more than one) occupies the middle of the mass.

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* There may be more than one.

PHYSIOLOGY.

1. **Nutrition.**—This is effected in the typical method described for green plants under Protococcus. The functions of chlorophyll are, of course, localized in the green band.

2. **Destructive Metabolism.**—(*Compare p.* 26).

3. **Reproduction.**—This is either vegetative or sexual.

(*a.*) **Vegetative Reproduction.**—The filaments can increase indefinitely in length by the bipartition of their cells, all of which possess this power. Division occurs, for the most part, during the night. In a cell which is about to divide, the nucleus undergoes important changes. It elongates and assumes the form of a spindle with its poles directed towards the ends of the cell. The centre of the spindle is occupied by an *equatorial plate*, from which striæ converge to the poles. This plate divides into two halves, which travel away from one another, thus giving the nucleus the form of a dumb-bell, the ends of which become separate, and form the nuclei for the two new cells.

Meanwhile, an annular rim of cellulose has been gradually growing inwards, and at last becomes converted into a septum. The growth of this divides the primordial utricle with its chlorophyll band into two parts. The original cell is now divided into two new ones, which elongate and attain the adult size. During the processes above described, active "streaming" may be observed in the protoplasm, currents with suspended granules moving in various directions. These granules are known as *microsomata*, and the new septum appears to be built up from them. It seems probable that *all* cell-walls are built up from such minute particles.

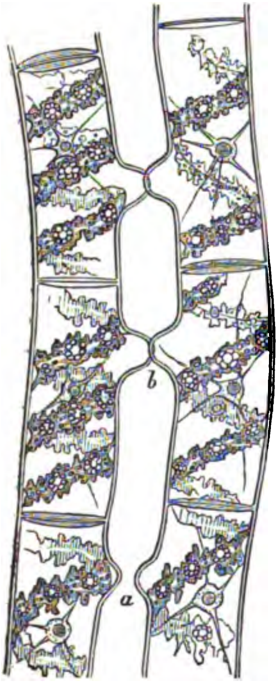

Fig. 7.—CONJUGATION OF SPIROGYRA, early stages, much enlarged (from *Sachs*).—*a* and *b*, Successive stages of conjugating process.

This process of vegetative division very constantly goes on, and filaments which attain any considerable length easily get broken into pieces, which become new plants. Under unfavourable circumstances a process of "segmentation" takes place, the individual cells separating by a splitting of the septa, sometimes in a very peculiar manner. This, however, in nature seems to be merely a prelude to the complete dying-down which takes place on the approach of winter.

(*b*.) **Sexual Reproduction** is effected (Figs. 7 and 8) in the summer by a process of conjugation. The cells of neighbouring filaments (more rarely adjacent cells of the same filament) conjugate in pairs. From either cell a blunt projection (Fig. 7, *a*) grows out, which meets with the one from the other cell (*b*). At the point of contact, the wall becomes absorbed, and a connecting tube is thus formed. At the same time, the protoplasm of each cell contracts into a rounded mass. Most of the cell-sap passes out into the space now formed immediately within the cell-wall. One of the masses of protoplasm then (Fig. 8, A, *a*) squeezes through the connecting tube, and fuses with the other mass to form a *zygospore* (Fig. 8, A, *b*, and B). It should be remarked that the protoplasm of the active (male?) cell contracts before that of the passive (female?) cell. A condensation of protoplasm would appear to occur in the process of fusion, for the zygospore is much smaller than the sum of the volumes of the conjugating masses. The zygospore forms for itself three cell-walls, two firm outer and a delicate inner wall.

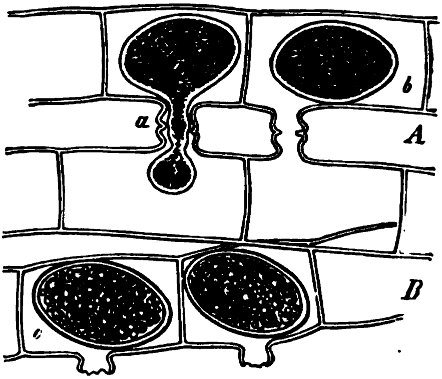

Fig. 8.—CONJUGATION OF SPIROGYRA, much enlarged (from *Sachs*).—A, Actual conjugation; *a*, protoplasm passing over; *b*, fusion. B, *c*, Young zygospores.

DEVELOPMENT.

The **zygospore**, protected by its three walls, and in addition by the old wall of the passive cell, remains in a dormant state during the winter as a "*resting*" *spore.* Within its protoplasm oil-drops and starch are contained as reserve materials, serving for the growth of the young plant before it begins to absorb food from the exterior. In the spring the two outer coats are ruptured, and a filament grows out covered by the innermost coat. This soon becomes divided up into cells. At first, the two ends of the young plant are dissimilar, there being an *apex* away from, and a *base* towards, the remains of the spore. This distinction, however, is soon lost.

§ 7. FUCUS (Wrack).

The large brown sea-weeds found upon the shore between tide-marks, and commonly known as *wrack*, are examples of Fucus. Three of the commonest species are *Fucus vesiculosus*, *Fucus nodosus*, and *Fucus serratus* (Fig. 9, A, B, C).

MORPHOLOGY.

1. **Vegetative Organs.**—The *Thallus*, or plant-body, of Fucus, when well developed, may attain a considerable length, and is attached to the rocks at one end by means of a sucker-like expansion (Fig. 9, A′) frayed out at the edges. The upper part of the thallus is more or less flat, and branches considerably.

The branching (which is dichotomous—*i.e.*, forked, in *F. vesiculosus* and *F. serratus*) may be well studied by laying out the plant on paper. All the branches are then, at least in young plants, seen to be in the plane of the paper. The colour is olive-green, which may be very dark in old specimens, or of a yellowish shade in young ones. In *F. vesiculosus* and *F. serratus*, a thickened *midrib* runs down the centre of each branch. The edges of the latter species are notched like the edges of a saw, *serrated.* In both the surface is dotted over with small tufts of minute hairs, which are absent in *F. nodosus.* Here and there the thallus in *F. vesiculosus* and *F. nodosus* is swollen into *air-bladders* (*a.b*), often paired or grouped in the former species, singly placed and much larger in the latter, where a length of 2 inches or more may be attained by them. They are caused by a hollowing out of the internal tissue, and serve for flotation, keeping the plant well spread out when covered by the tide.

Histology (Fig. 9, D).—A firm outer *rind* (*r*) made up of small, thick-walled cells can be distinguished, within the granular protoplasm, of which are small *chlorophyll corpuscles* to which the chlorophyll is limited, and which correspond to the similar corpuscles found in the spiral band of *Spirogyra*. The outermost cells of the rind may be regarded as constituting a rudimentary **epidermis**. This name is applied in the case of the higher plants to a definite, well-characterized, external layer. In *F. vesiculosus* and *serratus* there are numerous small depressions lined by epidermis, from which spring delicate filaments, each composed of a row of cells. These are *hairs*, and come under the broader heading of **trichomes**, in which are included all outgrowths formed from the epidermis alone.

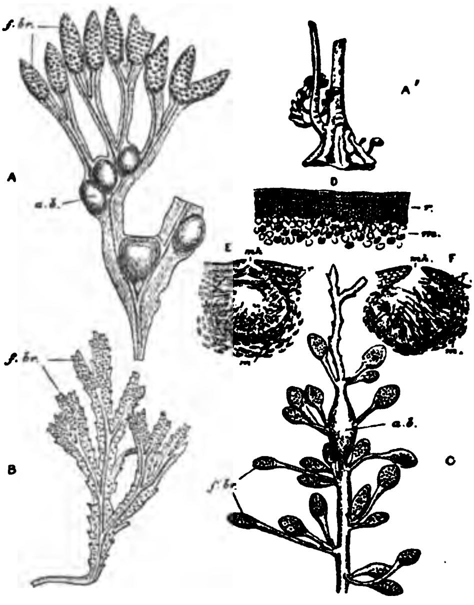

Fig. 9.—Fucus.—A, B, C, *Fucus vesiculosus*, *F. serratus*, and *F. nodosus*; A′, attachment disc of A—all reduced. D, Small part of transverse section of thallus of *F. nodosus*. E, Section through male conceptacle of *F. serratus*. F, Section through female conceptacle of *F. vesiculosus*—all enlarged considerably; *r*, rind; *m*, medulla; *a.b*, air-bladder; *f.br*, fertile branchlets; *mh*, mouth of conceptacle.

The internal part of the thallus or *medulla* (*m*) is much less compact, and formed of more transparent elongated cells, the walls of which possess an inner firm layer, and an outer layer "common" to the surrounding cells, which very readily becomes mucilaginous by imbibition of water. Filaments grow from the innermost part of the rind into the mucilaginous layer thus formed between the cells of the medulla, and unite together to form a network, in the meshes of which these cells come to lie. The chlorophyll corpuscles in the internal tissue are well seen, but in the rind they are much obscured by a brown colouring-matter, *phycophæin*. From an alcoholic extract of the dried plant which contains both this pigment and chlorophyll, the latter can be separated by benzine and its existence thus demonstrated. The branches grow at their ends, each of them possessing a terminal group of *apical-cells*, in shape like truncated pyramids. By cell-walls arising parallel to the sides and bases of these, segmental cells are formed, which add to the permanent tissue. Here and else-

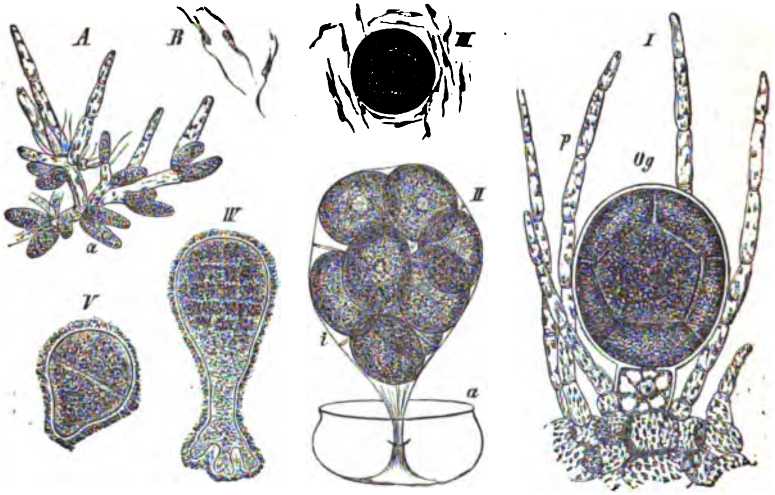

Fig. 10.—Sexual Reproduction of Fucus Vesiculosus, B × 330, the rest × 160 (from *Sachs*, after *Thuret*).—A, Branched hair with antheridia, *a*; B, spermatozoids. I. Oogonium, *Og*, with paraphyses, *p*. II. Expansion of oospheres within the inner membrane, *i*, which covers them after rupture of oogonium; *a*, remains of outer membrane. III. Free oosphere surrounded by spermatozoids. IV. Embryo plant. V. First division of oospore.

where it must be clearly understood that apical cells like these, from which segments are being cut off, enlarge after each division to their normal size before dividing again.

2. Reproductive Organs.—The ends of many ordinary branches in *F. serratus* and *F. vesiculosus*, and of special lateral branches in *F. nodosus*, are found swollen up in spring and summer. These are *fertile branches* (*f.br.*), which in *F. serratus* are flat. On holding a mature fertile branch up to the light, a large number of rounded semi-opaque bodies, about the size of small pins'-heads can be seen imbedded in the walls of its swollen end. These are in reality small pits, *conceptacles*, each of which opens on the surface by a minute pore, and is lined by the epidermis, of which it is a depression. The interior of the swollen end is especially mucilaginous, and the network in the medulla very distinct. The three species under consideration are *diœcious—i.e.*, the conceptacles are male or female, and only one kind occurs on the same individual.

(*a.*) The **male conceptacles** (Fig. 9, E) contain very numerous elongated unbranched *sterile hairs*, each of which is a cell-row. These project more or less from the mouth of the conceptacle. Between the sterile hairs is a smaller number of shorter fertile hairs, which branch considerably. Many of their branches are modified into unicellular male organs, the *antheridia* (Fig. 10, A). Each antheridium (*a*) is a small oval sac, the protoplasm of which divides into numerous minute *spermatozoids* (B), which are pointed at one end. Each possesses two long flagella attached to one side, and an orange spot in its interior.

(*b.*) The **female conceptacles** (Fig. 9, F) contain sterile hairs quite similar to those of the male. The female organs, *oogonia*, are far less numerous, but much larger, than the antheridia (Fig. 10, I.) Each oogonium arises as a small outgrowth from one of the epidermal cells lining the conceptacle. This outgrowth becomes separated from its mother-cell by a partition, and then divides into two cells, a lower and an upper. The mature organ consists of a short unicellular stalk and a rounded capsule, developed from these two cells respectively. The latter possesses a three-layered cell-wall, and its dark granular protoplasm divides into eight (four in *F. nodosus*) *egg-cells* or *oospheres*. These are closely pressed together, so that their outlines appear polygonal. Each possesses a distinct nucleus, but no cell-wall.

PHYSIOLOGY.

1. **Nutrition.**—As in green plants generally. The action of the chlorophyll is not interfered with by the brown pigment.

2. **Destructive Metabolism.**—*Compare p.* 13.

3. **Reproduction.**—The only, or at any rate the only important, method of reproduction is **sexual** by means of the spermatozoids and oospheres. The antheridia become detached, and collect together at the mouths of their conceptacles. Their walls give way at one end, and the spermatozoids escaping, move actively about by means of their flagella. The outer layer of the wall in the oogonia ruptures, and the oospheres, invested in the two inner and more delicate layers, pass out like the antheridia to the mouths of their conceptacles. The outer investment is partly disintegrated, partly springs back to form a kind of cup round the base of the inner investment, which is first distended and then ruptured by the expansion of the oospheres (Fig. 10, II.) These, when liberated, are naked spheres of protoplasm. The spermatozoids move actively around them, and cause rotation for a short time (Fig. 10, III.) Fertilization is ultimately effected (in all probability) by the fusion of a spermatozoid with each oosphere. Such a fusion of a small active male element with a passive and relatively large female element, is the most typical form of sexual reproduction.

4. **Contractility** is exhibited in the movements of the spermatozoids.

5. **Irritability** and **Spontaneity** are displayed by the same bodies, and more especially in regard to the oospheres.

DEVELOPMENT.

The fertilized oosphere (or **oospore**, as it is now termed) at once commences to develop (Fig. 10, IV., V.) A cell-wall is first formed, which is followed by numerous cell-divisions. A small flattened mass of tissue, which speedily attaches itself at one end by a rudimentary branched sucker results from these. The later stages of development are not known.

§ 8. CHARA AND NITELLA (Stoneworts).

These are comparatively large green plants, found most abundantly in the pools of chalk districts.

MORPHOLOGY.

1. Vegetative Organs.—The plant-body shows a well-marked distinction between base and apex. In it we see for the first time a distinction between **stem** and **leaf**, although only in a rudimentary way.

These terms are correlative. A *stem* is an axis bearing *leaves*, which develop close to the growing-point in acropetal succession. They originate as projections of the outer part of the stem (epidermis and subjacent tissue, not the former alone like trichomes), and differ more or less from this in shape. A stem with its leaves is termed a *shoot*.

The *stem* is very slender, but it may attain a considerable length. The base is fixed in the mud, while the rest of the plant floats more or less vertically in the water. The delicacy of the stem is made up for in Chara by a firm external crust of carbonate of lime. This is not, however, confined to the stem. Cylindrical *leaves*, arranged in circlets or whorls of 4-10, grow out from definite points (*nodes*) in the stem. The spaces between the nodes are called *internodes*. The leaves become smaller and the internodes shorter as the apex is approached, and the stem finally ends in a growing point, round which the smallest and youngest leaf-whorls are crowded to form a *terminal bud*. The leaves of any whorl are so arranged that they are not exactly underneath the leaves of the next whorl above. From the *axil* of the oldest leaf in a whorl a secondary axis or branch may grow out in Chara. Two branches may grow out in Nitella from the axils of the two oldest leaves.

The *axil* of a leaf is the angle between its upper surface and the stem.

Passing from the apex to the base of the plant, such lateral axes may be traced from the condition of mere buds to a state of considerable elongation. They terminate, and are otherwise constituted, like the main stem, and may themselves originate branches in like manner. In the lower parts of the plant, delicate tubular filaments also grow out from the nodes. These, as they play the part of roots (although not true roots in the botanical sense, *see p.* 57), are termed **rhizoids**. Tufts of secondary rhizoids may grow out from them. Like the stem, the leaves are divided on a small scale into nodes and internodes, From the leaf-nodes whorls of small *leaflets* grow out. Each leaflet commences with a *basal node.*

Histology.—The stem (Fig. 11) is terminated by a large hemispherical *apical cell* (*t*), by whose constant transverse division new cells are added, which, developing into nodes and internodes, add indefinitely to the length of the plant. The apical cell, together with its immediate products, constitutes the growing point.

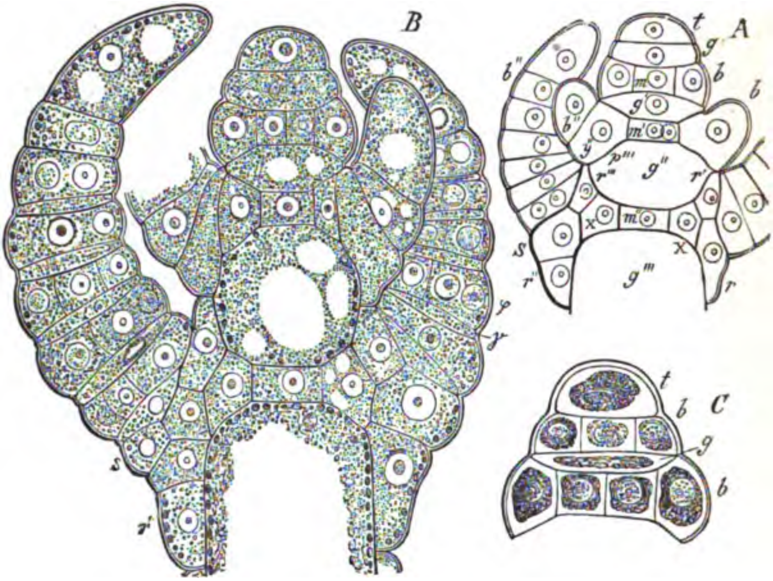

Fig. 11.—Longitudinal Section through Bud of Chara, much enlarged (C × 500) (from *Sachs*).—A, Cell contents partly left out. B, Granular substance protoplasm, larger granules chlorophyll, white spaces vacuoles. C, Cell contents contracted by iodine solution. *t*, Apical cell (in C about to divide, nucleus double); $g-g'''$, internodes (A, *g*, segmental cell); m—m'', nodes; *b*, leaves; *r*, cortex; γ and ϕ, internode and node of leaf.

The processes continually going on in the growing point are briefly summed up thus:—The nucleus of the apical cell divides transversely, and a transverse partition is then formed. Two cells are thus constituted—an upper, which remains as the new apical cell, and a lower or *segmental cell* (A, *g*). This quickly divides transversely into an upper biconcave *nodal cell*, and a lower biconvex *internodal cell* (C, *g'*). The former almost immediately divides into several smaller cells by longitudinal partitions, while the latter merely elongates.

Meanwhile the new apical cell has grown to the size of the old one; division again occurs, and another node and internode are added. Thus the plant is continually increasing in length. The nodes become by frequent division transverse plates, made up of numerous cells, the outermost of which grow out into leaves, lateral axes, and rhizoids. All the cell-divisions, here and elsewhere, are preceded by division of the nucleus. The internodal cells are, of course, very short at first; but as they increase in length, the nodes with their leaf-whorls are widely separated.

Each internode of the stem in Chara is covered by a thin layer of cells, known as the *cortex*. This is formed by a number of flaps, which grow out from the basal nodes of the leaves. The leaves of the whorl *above* each send a flap *downwards* (*r"*), while the leaves of the whorl *below* each send (with one exception) a flap *upwards*. These two sets of outgrowths dovetail together at their junction, so as to form a complete sheath to the internodal cell. Each flap is divided into nodes and internodes, and grows by means of an apical cell, so as to keep pace with the elongating internodal cell. This twists slightly as it grows, and hence the cortex is arranged somewhat spirally. If we imagine a number of simple flattened leaves closely applied to the stem, a good notion will be gained of the structure of the cortex. The *leaves* have very short internodes (γ), which are covered with a comparatively simple cortex. The leaf on its first formation grows by means of an apical cell, but its growth is limited—that is, after a certain length is reached, the apical cell divides no further, but remains as the large pointed and uncovered *terminal cell*. The *rhizoids* are made up of a small number of elongated cells, destitute of chlorophyll, and separated from one another by very oblique partitions.

The young cells of Chara and Nitella are quite full of protoplasm, but when they become older small vacuoles appear. These fuse together ultimately to form a large central vacuole, full of cell-sap. The protoplasm now lines the cell-wall as a primordial utricle, in which an outer layer, containing numerous chlorophyll granules, may be distinguished from an inner, clear layer, in which the nucleus is imbedded. This, however, may in old internodal cells break up into a number of smaller parts, which are then found scattered through the protoplasm. This process is known as *fragmentation*.

2. **Reproductive Organs** (Fig. 12).—These appear in the summer as outgrowths of the leaf-nodes on the side next the stem. All the common kinds of both Chara and Nitella are *monœcious*—*i.e.*, male and female organs are found in the same plant. It will be convenient to describe first the reproductive organs of Chara.

(*a*.) The **male organ** or *antheridium* (*a*), which may be regarded as the modified end of a leaflet, is a minute globular body,

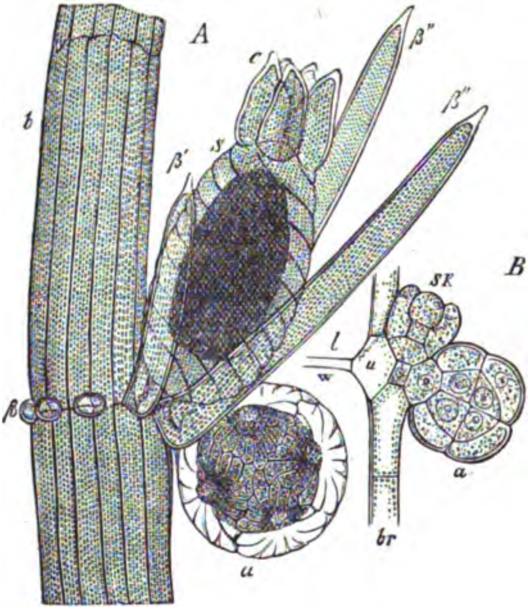

Fig. 12.—Reproductive Organs of Chara (from *Sachs*).—A, Middle part of leaf (*b*) with antheridium (*a*) and oogonium (S) with its crown (*c*); β, sterile lateral leaflet; β', large lateral leaflets; β'', bracteoles (× about 50). B, Young antheridium (*a*) with still younger carpogonium (SK); *w*, nodal cell of leaf; *l*, cavity of internode of leaf; *br*, cortex (× 350).

attached by a very short broad stalk. When young, it is green; when ripe, orange in colour; but, in either case, a clear margin is seen when it is viewed by transmitted light. In structure the antheridium is a hollow sphere, the walls of which are made up of eight plate-like cells, known as *shields*. The four furthest away from the stalk are triangular, the others four-sided. A *stalk-cell* penetrates between the junction of these last. The outside of each shield is marked by furrows, which run from its sides towards its centre. The inner layer of the shield contains, in the young state, chlorophyll granules, which later on become orange-coloured. Hence the difference in hue between the young and old antheridium. From the centre of each shield (Fig. 13, B) a cylindrical cell, the *handle* (*m*), projects into the cavity of the sphere. Upon the end of this is a rounded *head-cell*, which bears six smaller *secondary head-cells*, to each of which four elongated *filaments* (*f*) are attached. It is these filaments which mainly fill up the internal cavity. Each of them is divided by numerous transverse partitions into 100–200 flattened cells, the protoplasm of which gives rise to the *spermatozoids*, minute spiral bodies, the posterior ends of which are thickened, the anterior pointed, and bearing two elongated flagella.

(*b.*) The **female organ** or *oogonium* (S) is developed from the basal node of the same leaflet. It is an oval body, placed above the antheridium, the wall of which is formed by five tubular, spirally-twisted cells, upon the free ends of which are placed the five pointed *crown-cells* (*c*) making up the crown. These investing cells contain chlorophyll-granules, which after fertilization become orange coloured. The interior is occupied by a large oval *egg-cell* or *oosphere*, which possesses an abundance of starch-grains and oil-drops. It is invested in an extremely delicate membrane, except at the top, where it exhibits a somewhat conical mass of clear protoplasm—the *apical papilla*. Below the egg-cell at an early stage, a small clear inconspicuous cell (*Wendungszelle*) may be seen. Beneath this again is a *stalk-cell*, enclosed in the twisted coatings. Above the oosphere is a space, roofed in by the crown-cells, and almost divided into two halves by a transverse partition, which, however, has a small hole in its centre. When ripe, this cavity is full of a transparent mucilage.

The sexual organs of *Nitella* are placed differently from those of Chara. The antheridium is the modified end of a leaf, from the last node of which

two oogonia are developed. These are placed below the antheridium. Both sexual organs are similar in structure to those of Chara, but the oogonium has ten small instead of five large crown-cells, and these form two rows placed one above the other. There are also several *Wendungszellen*, and the stalk-cell is not completely enclosed by the twisted envelope.

PHYSIOLOGY.

1. **Nutrition** is effected in the manner typical of green plants. All the cells, except those of the rhizoids, contain chlorophyll granules, and hence assist in the work of nutrition. The surface position of the granules is in accordance with their function.

2. **Destructive Metabolism.**—As usual.

3. **Reproduction.**—Vegetative and sexual.

(*a.*) **Vegetative reproduction** is effected in Chara by means of —(1) *Starch-stars* or *bulbils*, underground nodes which possess numerous whorls of short leaves and are crammed with starch. These are capable of becoming detached, and buds afterwards form in their leaf-axils. (2) *Branches with naked base*—that is to say, destitute of cortex where they first come off from the stem. These are detachable, as are the (3) *Pro-embryonic branches*, which resemble the pro-embryo described below, and give rise to new plants in the same manner.

(*b.*) **Sexual reproduction.**—The antheridia and oogonia in the same plant are not ripe at the same time, and thus *self-fertilization* is avoided and *cross-fertilization* secured, the spermatozoids of one individual fertilizing the oospheres of others.

When ripe, the shields of the antheridium are elastic, and tend to become flat, thus separating from one another. The spermatozoids escape from their cells, and by means of their flagella move actively through the water. Meanwhile, the gelatinous substance in the apex of the carpogonium has swollen up by imbibition of water, and forced the crown-cells somewhat apart, making small fissures between them. Through these the spermatozoids enter, and, one or more making their way through the gelatinous substance, fuse with the apical papilla, and thus effect fertilization. The oosphere becomes an oospore, and, enclosed in the oogonium, the walls of which turn black, falls to the bottom of the water to germinate in the following spring.

4. **Contractility.**—In all the cells of Chara a *rotation* of protoplasm takes place—that is, the inner clear layer of the primordial

utricle continually moves *round* the cell in its longest direction. Where the up and down currents pass each other, there are two streaks, the *neutral lines,* maintained in a state of rest.

The movements of the spermatozoids afford another example of contractility.

5. **Irritability** and **Spontaneity** are exhibited, as in Fucus, by the spermatozoids (Fig. 13).

DEVELOPMENT.

The **oospore** divides by a partition transverse to the oogonium into an upper *nodal cell,* and a lower, much larger *basal cell,* which merely serves as a reservoir of nutriment. The nodal cell divides into two other cells, from one of which a delicate rhizoid is developed, the so-called "*primary root,*" whilst the other grows out into a slender filament, the axis of the pro-embryo. This, when fully developed, consists of a long, clear, internodal cell near the basal cell, a short root-node from which a bunch of rhizoids grows out (*r.n*), an internode covered with a deposit of carbonate of lime, a short stem-node (*s.n*), and a terminal part divided into chlorophyll-bearing cells by transverse partitions. From the stem-node a tuft of leaves arises, in the centre of which an ordinary terminal bud develops. This grows into a Chara-plant. Chara thus presents another case of *alternation of generations,* the ordinary plant being the sexual **oophyte,** while the pro-embryo is the asexual **sporophyte.**

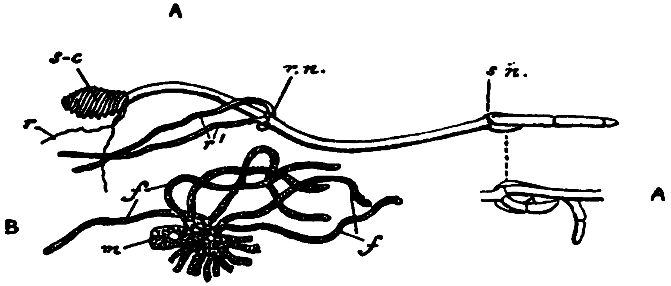

Fig. 13.—PRO-EMBRYO AND PART OF ANTHERIDIUM OF CHARA, enlarged.—A, Pro-embryo; *s.c*, oogonium; *r*, *r'*, rhizoids; *r.n*, root-node; *s.n*, stem-node (A' below is same region of older pro-embryo). B, Handle (*m*), with head-cells and filaments (*f*).

CHAPTER III.—THE MOSS.

§ 9. FUNARIA AND POLYTRICHUM (Mosses).

Funaria hygrometrica is common on walls. Several kinds of *Polytrichum*, differing mainly in regard to size, are abundant in woods and on moors.

MORPHOLOGY.

A very well-marked *alternation of generations* is present, and it will be most convenient to describe the asexual and sexual generations separately.

I. SPOROPHYTE.—This is commonly known as the "moss-fruit," and to all outward appearance is part of the oophyte in which it is embedded, and upon which it is dependent. In both *Funaria* (Fig. 14) and *Polytrichum* the **sporogonium** (as the sporophyte is here termed) consists of a thin, reddish-brown stalk or *seta* (*p*) firmly fixed in the oophyte at one end, and bearing a dilated *capsule* (*u*) or *theca* at the other. In *Funaria* the seta curves round at its end, and the pear-shaped capsule is borne obliquely. At its tip a small rounded *lid* (*o*) or *operculum* may be distinguished; this, in the younger capsules, is covered over by a pointed cap, the *calyptra* (*c*), which does not in reality belong to the sporophyte. The operculum falls off from the ripe capsule, and sixteen delicate pointed processes are then seen projecting from the edges of the capsule towards its centre. Below these are sixteen similar processes. The thirty-two together make up the *peristome*, which forms a kind of imperfect partition across the mouth of the open capsule. This probably regulates the escape of the spores. In *Polytrichum* the capsule is upright and four-angled. It possesses a *lid* from which a short point projects, and is largely covered by a conspicuous *calyptra*, the edges of which are frayed out. The peristome is complicated, and is made up of a

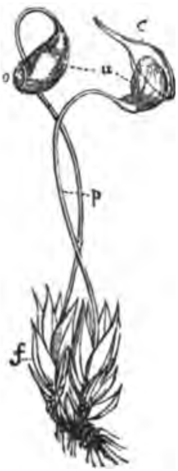

Fig. 14.—FUNARIA HYGROMETRICA, enlarged.—*f*, Leaves; *p*, seta; *u*, capsule; *o*, operculum; *c*, calyptra.

large number of short, pointed processes, projecting inwards, the ends of which are united by a perforated membrane.

Histology.—*Funaria* may be taken as a type. The capsule is formed by an outer *wall;* within this is a large *air-space* into which projects a central plug of tissue. The air-space does not extend into the region of the lid, nor into the base. A very definite *epidermis*, composed of cells, the outer walls of which are much thickened and cuticularized,* covers the outside of the capsule. Around the margin of the lid there is a thickened rim, the *annulus*. The epidermal cells are here much elongated and their party-walls are thickened. At this point, a split runs round the margin of the ripe capsule, by which the lid is separated. There are small openings, *stomata*, in the epidermis, each bounded by two curved *guard-cells* (*see Chap. VI.*) Within the epidermis, in the region of the air-space, two or three layers of thin-walled *parenchymatous* cells (*i.e.*, cells fairly equal in their different dimensions) are found, scantily provided with chlorophyll granules. Internal to these, again, is an irregular layer of small cells rich in chlorophyll, which forms the outer boundary of the air-space. This last is traversed by delicate threads, composed of short chlorophyll-containing cells, which run from the layer last described to the central plug. The base of the capsule is mainly made up of small-celled parenchyma. The interior of the central plug is occupied by a core of large-celled colourless parenchyma forming the *columella*. This, on the one hand, is continuous with the lid (which is merely a part of the capsular wall), and, on the other hand, is connected with the base by a number of the filaments above mentioned, closely united together. Covering the sides of the columella there are several layers of small cells, making up the *spore-sac* and the *sporogenous layer*. The former is composed of small celled chlorophyll-containing parenchyma, disposed in a single layer, the *inner* spore-sac, next the columella, and two or three layers, the *outer* spore-sac, next the air-space. Between these inner and outer parts of the spore-sac, comes the brownish *sporogenous layer*. This is at first composed of large granular cells, with well-marked nuclei. Each of these divides by two successive walls at right angles to one another into four *spore-mother-cells*. These separate, and lie loosely within the spore-sac, the protoplasm of each finally dividing into four rounded parts which are arranged tetrahedrally within the wall of the mother-cell. This they eventually rupture, having developed cell-walls of their own, and escape as the *spores*.

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* *i.e.*, The cellulose walls chemically altered into *cutin*, a wax-containing substance closely allied to cork.

The narrow pointed flaps, making up the peristome, arise as local cell-wall thickenings, which become separate by the falling off of the lid, and the drying up of the columella. At the same time that the spore-sac is ruptured, the ripe spores can escape. These spores are spherical nucleated cells, containing chlorophyll granules, and invested by a delicate *endospore* and firmer thickened and cuticularized *exospore*.

The *seta* possesses an external epidermis, underlying which are thick-walled cells. The axis is occupied by a bundle of small and narrow cells, which are *prosenchymatous*—*i.e.*, dovetailed together by their tapering ends. They are separated by thin-walled parenchyma from the thick-walled layers beneath the epidermis. The base of the seta is firmly fixed in the oophyte, with which, however, its cells are *not* continuous.

II. OOPHYTE.—This is the "moss-plant" so-called, and is more important, though less highly developed, than the sporophyte.

1. Vegetative Organs (Fig. 14).—Stem and leaf (*f*) are well differentiated, and numerous rhizoids are present in the lower part of the plant.

The narrow cylindrical *stem* is firm and brown. Numerous *leaves* are crowded together upon it. These (in *Funaria*) are thin green plates, pointed at one end and attached to the stem by the other without the intervention of a stalk—*i.e.*, they are *sessile*. The leaves are arranged spirally. The *rhizoids* are branching filaments, brown in colour, attached to the lower parts of the stem, and penetrating into the substratum.

Histology.—The stem is similar in structure to the seta, but its epidermis is not so well defined. It grows by means of an *apical cell*. This is a three-sided pyramid, the curved base of which is directed outwards. From the three sides in rotation flat *segmental cells* are cut off, which divide to produce the various kinds of permanent cells. The earlier walls dividing any particular segmental cell are longitudinal, and the first of these, or *leaf-wall*, separates an *outer* cell, which produces a leaf and part of the exterior of the stem from an inner cell, which gives rise to part of the internal stem-tissue. When a branch is formed, it commences as a bulging from an *outer* cell, just below the corresponding leaf, and its apical cell is originated by oblique walls which intersect.

The *leaves* (in *Funaria*) are made up of flattened cells, containing numerous chlorophyll-granules. A single layer of such cells makes up the sides of each leaf, but the centre is occupied by a "midrib,"

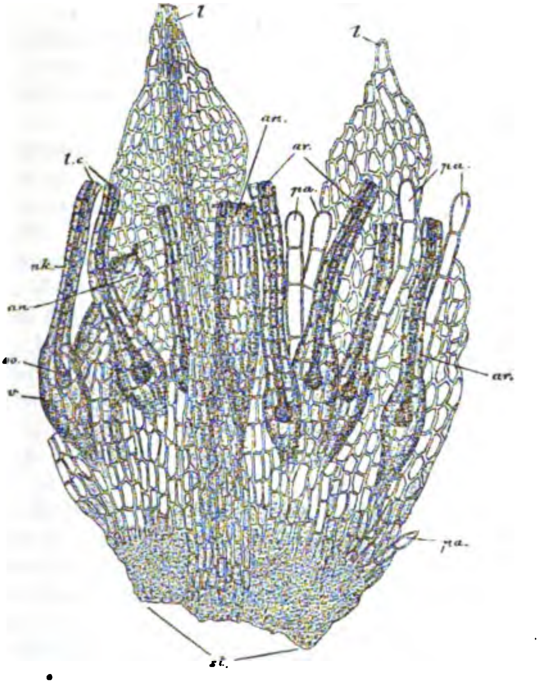

Fig. 15.—Reproductive Organs of a Moss (*Cynclidium stygium*), much enlarged.—*an*, Antheridia; *ar*, archegonia; *l.c*, lid-cells; *oo*, oosphere; *nk*, neck; *v*, venter; *st*, stem; *pa*, paraphyses; *l*, leaves; *st*, stem.

which is traversed by several layers of narrow elongated cells, similar to and continuous with those occupying the centre of the stem. The leaves of *Polytrichum* are covered with greenish scale-like projections. The *rhizoids* are entirely derived from the epidermis, and hence come under the category of *trichomes*. Each of them is made up by a row of somewhat elongated cells, separated by oblique septa. The walls of these cells are brown and thickened, and their protoplasm contains numerous oil-drops, but is devoid of chlorophyll. Branches grow out behind the septa, and both these and the main rhizoids grow apically. The end-cell elongates, and the cell-row is augmented by new cells cut off by oblique partitions. The young growing ends are closely covered with particles of soil.

2. **Reproductive Organs** (Fig. 15).—Both *Funaria* and *Polytrichum* are *diœcious*, and this is the commonest condition. Fig. 15 is taken from a moss in which a *bisexual* arrangement is found, male and female organs occurring together.

(*a*.) The **male organs** or *antheridia* are closely crowded together at the end of the main stem. They are borne on smaller male plants and surrounded by an investment of leaves, which in *Funaria* differ but little from the ordinary ones. These leaves make up the *perigonium*. In *Polytrichum* the antheridia are placed in the axils of the perigonial leaves, which are shaped very differently from the foliage-leaves, and are red or orange in colour. A very conspicuous structure is thus formed.

Each antheridium (*an*) is a club-shaped sac, the wall of which is formed by a single layer of flattened cells, green when young owing to chlorophyll-granules, and brown when old. The base of the sac is attached by a short and narrow stalk, composed of small cells. The interior of the antheridium is filled with numerous small *spermatozoid-mother-cells*. Each of these becomes rounded, and its protoplasm is converted into a short spiral *spermatozoid*, the anterior end of which possesses two long flagella, while the posterior end is thickened. Scattered among the antheridia are numerous hairs, the *paraphyses* (*pa*), which are brown when old. A paraphysis of *Funaria* is made up of a row of cells, the end one of which is globular.

In *Polytrichum* these bodies are expanded at their ends into narrow plates made up of several rows of cells.

(*b*.) The **female organs** or *archegonia* (*ar*) are surrounded by a *perichætium*, composed of foliage-leaves but little modified. These bend over and largely conceal the groups of archegonia. Each archegonium is a flask-shaped body, in which a narrow slightly-twisted *neck* (*nk*) may be distinguished from a dilated ovoid *venter* (*v*), supported on a short stout stalk composed of several rows of cells. The outer cells of the young archegonia contain chlorophyll-granules, but a red or brown colour is subsequently assumed.

The wall of the venter is two-cells-thick, that of the neck is composed of a single layer of cells arranged in about four longitudinal rows. The four end-cells of the neck are termed *lid-cells* (*l.c*), and are at first closely apposed. The archegonium contains an axial row of cells, of which the largest and most important is the rounded *oosphere* (*oo*), which occupies most of the cavity in the venter. Above this is a small *ventral-canal-cell* (polar-cell). The axis of the neck is occupied by a row of small elongated *neck-canal-cells.* Numerous simple paraphyses are scattered among the archegonia.

PHYSIOLOGY.

1. **Nutrition.**—The green parts are concerned as usual with the utilization of the carbon dioxide of the air, while the young ends of the rhizoids absorb nutriment from the soil, which, as before mentioned, adheres closely to them. The elongated cells found in the centre of the stem, and in the midribs of the leaves, appear to represent in a rudimentary way the vascular bundles (p. 52) of higher plants, which serve as channels by which solutions of food, &c., can pass from one part of the plant to another.

2. **Destructive Metabolism.**—The leaves are here the organs of **respiration.**

3. **Reproduction.**—1. The *sporophyte* produces spores **asexually.** These germinate and give rise to oophytes, but not directly. The seta and wall of the capsule can also, if detached and kept damp, produce new oophytes **vegetatively,** protonema (*see below*) being first formed.

2. The *oophyte* produces new oophytes **vegetatively** in a large number of different ways—

(1.) By *innovation,* the old parts dying down, while the ends of the stems become separate plants.

(2.) By growth from any part of the stem or leaves of a *protonema.* This is a much-branched filamentous structure, the cells of which are elongated and divided by oblique partitions, resembling, in fact, the cells of the rhizoids. The resemblance is carried still further by the main axes of the protonema, which run along or penetrate into the soil, and possess cells with brown thickened walls. From these axes ascending branches grow out, which cannot increase indefinitely in length, and possess abundant chlorophyll. Upon these lateral buds are developed, which become leafy oophytes.

(3.) The rhizoids can act like the main axes of a protonema, developing green ascending protonemal branches, on which lateral buds arise as before. In many cases moss-stems die down in summer, but the rhizoids persist and produce new leafy stems in the autumn. This phenomenon has been observed in both *Funaria* and *Polytrichum*.

(4.) In *Funaria* the rhizoids can produce small rounded masses of cells, *underground buds*, which later on develop protonema, &c.

(5.) The stems of some mosses, though not of *Funaria* or *Polytrichum*, give rise to *gemmæ*, lenticular bodies, composed of chlorophyll-bearing cells. These may grow from the leaves or be contained in a special cup-like receptacle at the end of the stem, to the bottom of which they are attached by slender stalks. From the edges of these gemmæ protonemal filaments can grow out.

The occurrence of these numerous methods of vegetative reproduction accounts for the growth of most mosses in large patches, composed of innumerable individuals closely matted together by their rhizoids.

The *oophyte* reproduces **sexually** to form sporophytes. The ripe antheridia contain fully formed spermatozoids, enclosed in delicate vesicles made by the wall of the mother-cells. These vesicles are imbedded in mucilage, which swelling up by imbibition of water, ruptures the apex of the antheridium, and allows its contents to escape. The mucilage then dissolves in the surrounding moisture, and the spermatozoids, escaping from their vesicles, move actively about. The canal-cells of the ripe archegonium become converted into mucilage, which swells up, forces the lid-cells apart, and projects from the orifice. Spermatozoids are attracted by a sugary substance present in the mucilage (the viscidity of which retains them), and make their way down to the oosphere, which is fertilized by fusion of one of them with it, and becomes an oospore.

4. Contractility, and **5. Irritability** and **Spontaneity** are displayed by the spermatozoids.

DEVELOPMENT.

1. The **sporophyte** always develops as the result of sexual reproduction exhibited by the oophyte. The *oospore* is first divided by several transverse walls, and a wedge-shaped apical-cell is then developed, by means of which it grows. The end of the neck of the archegonium withers, but the rest of that organ continues for some time to keep pace with the growth of the embryo. This becomes a narrow cylindrical body, pointed at both ends, and on the one hand penetrating into the tissue of the oophyte, on the other extending into the neck and pressing against its withered end. Ultimately, the embryo grows faster than the archegonium, which is ruptured in consequence, part of it being carried upwards as the calyptra. After the sporogonium has attained its full length, the apical-cell disappears, and the free end gradually swells up into the capsule, which is at first a solid structure, but later on develops its air-space.

2. The **oophyte** may arise vegetatively, as has already been seen, either from the sporophyte or another oophyte. These, however, are accessory processes, and in the regular course of the life-history it develops from spores produced by the asexual sporophyte. The exospore of a germinating spore splits; two cells of unequal size are then formed by division, from one of which a colourless rhizoid grows out, from the other a chlorophyll-bearing *germ-tube*, from which a *protonema* grows, the ascending branches of which produce leafy oophytes as lateral buds in the same way as described before. It is noticeable that, both here and in most of the vegetative methods, the development of the oophyte is preceded by the formation of protonema. It is, therefore, convenient to apply the prefix *primary* to the protonema developed from the spore in the direct line of descent, while protonema developed in the accessory vegetative processes may be called *secondary*.

CHAPTER IV.—THE FERN.

10. PTERIS AQUILINA AND NEPHRODIUM FILIX-MAS (Bracken and Male Ferns).

These two forms may be regarded as our commonest native species. They are both of large size, and taken together illustrate well the group to which they belong.

It may not be superfluous to remind the beginner that the term "male" has nothing whatever to do with sex. The name "*male*" *fern* is a popular one, given to distinguish the plant from another form, the "*lady*" *fern* (*Athyrium filix-fœmina*), somewhat similar in appearance, but more delicate and graceful.

MORPHOLOGY.

As in the mosses there is a well-marked *alternation of generations*, and the two stages are completely independent. The sporophyte is very much larger, and far more highly developed than the oophyte.

I. SPOROPHYTE—1. Vegetative Organs.—Here we meet for the first time with all the parts found in higher plants—*i.e.*, *stem*, *leaf*, *root*, and *trichome*. These headings include every organ, and have reference to (relative) position and mode of origin, function being disregarded. Structures which agree in these respects are said to be *homologous*, or to display *homology*. The word "*trichome*," for example, is applied to all outgrowths from the epidermis, which the deeper tissue does not help to form—*e.g.*, the reproductive organs of Fucus, and the rhizoids of mosses. On the other hand, structures which perform the same functions are *analogous*, and display *analogy*. These terms are irrespective of position and mode of origin. The antheridia of Chara and Fucus, for example, both produce male elements, and are therefore analogous; but they are not homologous, being the modified ends of leaflets, and the branches of trichomes respectively.

(1.) **The Stem.**—*External Characters.*—This in the Bracken (Fig. 16, F,G) is a creeping underground *Rhizome*, which branches dichotomously, and may extend over a considerable area. In form it is cylindrical, and brown in colour. A paler streak, the *lateral line* (*l.l*), may be distinguished on either side. The end of each stem ends in a soft rounded knob, which is the growing point (*g.p*).

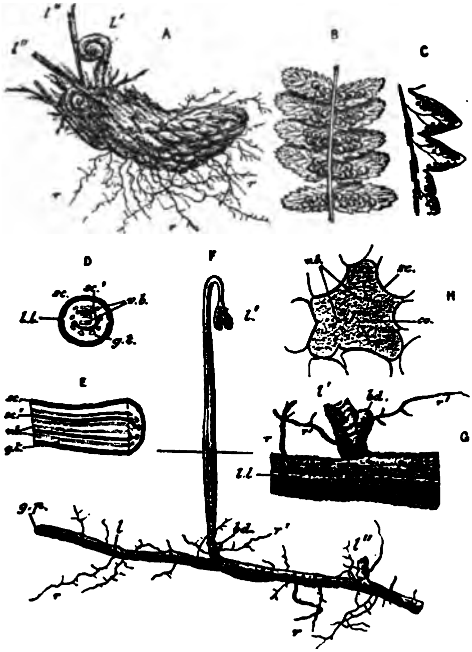

Fig 16.—The Fern, various scales.—A, Male Fern; *r*, root; *l′*, current year's leaf; *l″*, last year's leaves. B, Part of pinna, Male Fern, showing sori; C, ditto of Bracken; D, transverse section of Bracken rhizome; *l.l*, lateral line; *sc* and *sc′*, external and internal sclerenchyma; *v.b*, vascular bundles; *g.t*, ground tissue. E, Longitudinal section of ditto, letters as before. F, Part of rhizome of Bracken; *g.p*, growing point; *r* and *r′*, roots arising from rhizome and base of leaf stalk; *l*, next year's leaf as a bud; *l′*, current year's leaf; *l″*, last year's leaf; *bd*, bud; horizontal line is level of ground. G, Part of F enlarged, letters as before; *l.l*, lateral line. H, Transverse section of Male Fern stem; *p*, pith; *co*, cortex; *v.b*, vascular bundles; *sc*, sclerenchyma.

In the Male Fern (Fig. 16, A), the short stem grows obliquely upwards, and does not branch. It is completely covered and concealed by the stumps of the old leaf-stalks, which persist for an indefinite time. The growing-point forms the centre of a terminal bud, the outer parts of which are made up of numerous young leaves.

Anatomy.—All the kinds of tissue found in higher plants are here present, and may be classified as follows :—

A. Formative Tissue or Meristem.—Embryo and growing points.

B. Permanent Tissue
- 1. *Epidermis.*—A special external investing layer.
- 2. *Vascular Bundles.*—Aggregates of fibrous and tubular elements traversing the plant.
- 3. *Ground Tissue.*—Between 1 and 2.

In the stem of the Male Fern, which is in this respect more typical than the Bracken, the vascular bundles make up a hollow cylinder near the periphery. The walls of this are in the form of a network, with large diagonal meshes. Each of these being opposite the origin of a leaf-stalk is known as a *foliar gap*, and from its margin small bundles run out into the leaf-stalk. In cross-section (Fig. 16, H) the cut network appears as a ring of small oval areas (*v.b*), outside of which are numerous similar but smaller areas, due to the severed leaf-bundles. The *ground tissue*, in which the bundles are imbedded, is for the most part of yellowish tint, but almost immediately beneath the epidermis there is a narrow band of brown *sclerenchyma* (*sc*). The greater part of the ground tissue is within the vascular cylinder, and is known as the *pith* (*p*).

The rhizome of the Bracken differs in several important respects from the above description (Fig. 16, D, E). There are two vascular cylinders, and sclerenchyma is abundantly present. It may be divided into *outer* sclerenchyma (*sc*), a fairly broad band underlying the epidermis, except at the lateral lines (*l.l*), where it is absent; and *inner* sclerenchyma (*sc'*), scattered throughout the remainder of the ground tissue. Two especially large masses may be noticed in cross-section, between the vascular cylinders, above and below.

Histology.—For this the Bracken may be taken as the type, as the Male Fern presents no important differences.

(*a.*) **Meristem.**—Each branch of the rhizome terminates in a *growing point*, densely covered with brown hairs. In this is a small depression, at the bottom of which is placed the actual end of the stem. This is formed by the curved base of the wedge-shaped *apical-cell.* The sides of the wedge are placed right and left, and from them flat *segmental cells* are cut off right and left. These divide repeatedly, and form a small mass of meristem, which gradually shades into the permanent tissue.

The Male Fern has a three-sided apical-cell.

(*b.*) **Epidermis.**—A single layer of small flat cells, with brown walls, thickened externally.

(*c.*) **Vascular Bundles.**—Each is invested by two sheaths —(1) The *bundle-sheath* (endodermis) formed by a single layer of small flattened cells, somewhat yellow in colour (Fig. 17, *sg*); (2) the *phloem-sheath*, made up of a single layer (in the Male Fern of

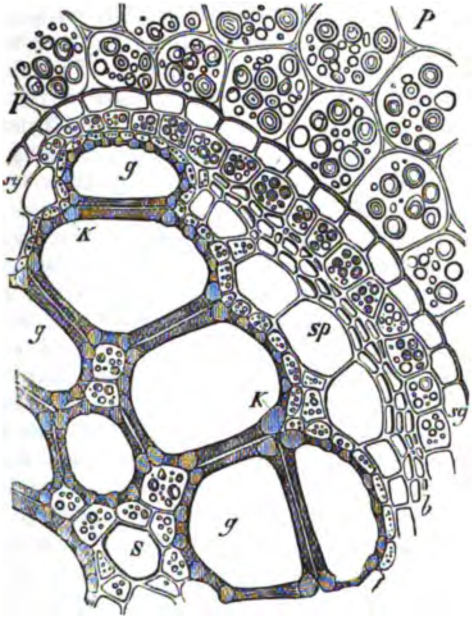

Fig. 17.—TRANSVERSE SECTION OF VASCULAR BUNDLE IN RHIZOME OF BRACKEN, × 300 (from *Sachs*).—*p*, Ground tissue; *sg*, bundle sheath, beneath which is phloem-sheath as a single layer; *b*, phloem-fibres; *sp*, sieve tubes; *g*, scalariform vessels; *s*, spiral vessels.

more than one layer) of small parenchymatous cells containing starch (just within *sg*). The bundle proper within the sheath is made up of two parts—external Phloem (bast) and internal Xylem (wood). (1.) The **Phloem** consists externally of two or three rows of somewhat elongated cells, the *bast-fibres* (*b*), the cellulose walls of which are much thickened. These being the first formed bast elements are termed *proto-phloem.* Internal to this is one or more layers of *sieve tubes* (*sp*), much larger and more elongated cells, tapering at their ends, and appearing polygonal in cross-section, with a thin lining of protoplasm. Upon their thin side-walls, where abutting upon similar structures, are very numerous *sieve-plates*, irregular areas, riddled with minute holes. These are generally so numerous that the narrow boundaries between them form a sort of network. The sieve-plates of adjacent tubes correspond, and fine threads of protoplasm pass through the pores from cell to cell. (2.) The **Xylem** is mainly composed of elongated, prismatic, and air-containing tubes, made up of large cells, dovetailed together by their tapering ends. These are *scalariform vessels* (*g*), the former term being given on account of the transverse ladder-like markings presented by them in side view. Their walls have been very much thickened by the apposition of internal layers, *except* where the markings occur. These are slit-like *pits*, opening internally into the cavity of the vessel, and closed externally by the thin *pit-membrane*, part of the original unthickened wall. The pits of adjacent vessels correspond, and were it not for the pit-membranes, they would communicate with one another. In the centre of the Xylem a few *spiral* and *annular vessels* occur (Fig. 17, *s*). These are narrow tubes formed like the other vessels as *cell-fusions*—that is, a number of cells placed end to end, come to form a continuous tube by the more or less complete absorption of the partitions which separate them. These vessels are termed *protoxylem*, being the earliest formed xylem-elements. Spiral or annular markings occur in these structures due to special internal thickenings.

In the Male Fern the xylem is made up of scalariform, spiral, and annular *tracheides*, *i.e.*, elongated air-containing cells.

The walls of the preceding xylem-elements are not only thickened but *lignified*—*i.e.*, converted from cellulose to *lignin*, a mixture of substances to which the properties of *wood* are due.

Both phloem and xylem contain numerous small starch-holding cells, making up the *phloem-* and *xylem-parenchyma*, or, collectively, the *conjunctive-parenchyma.* This forms, so to speak, a packing tissue, which fills up the interstices between the larger elements of the bundles. The type of bundle just described, in which the phloem surrounds the xylem, is known as *concentric.*

(*d.*) **Ground Tissue.**—This is chiefly made up of large parenchymatous cells (Fig. 17, *p.* 53) with thin walls. These cells contain abundance of starch in their protoplasm. They are polygonal in transverse, and somewhat rectangular in longitudinal section. The cells of the *sclerenchyma* are prosenchymatous, and their walls are thickened, lignified, and pitted in a peculiar manner.

The bundle and phloem-sheaths are probably modifications of the ground-tissue.

(2.) **The Leaf.**—*External Characters.*—The arrangement of the young leaves in the bud—*i.e.*, their *prefoliation* or *vernation*—is very characteristic. They are rolled up so as to present a crook-like appearance when unfolding (Fig. 16, *e′*). This is *circinate vernation.* Leaf-buds arise from the stem, and in the Male Fern the young leaves are crowded round the apex of this, or they may appear on the bases of the old leaf-stalks (Fig. 16, F, G, *bd*).

The mature leaves of the Male Fern, which are from 1–3 feet long, are arranged in a short spiral near the end of the stem. Further from the apex are the bases of old leaf-stalks. Each leaf consists of a long stalk, on either side of which is a row of flattened green expansions, the *pinnæ.* The leaf is termed *pinnate,* from the arrangement of these—*i.e.*, the axis with lateral outgrowths somewhat resembles a feather. The pinnæ are deeply lobed in a pinnate or feathery manner.

The leaves of the Bracken are arranged in two rows, the members of which alternate. If a plant is dug up in the middle of summer, the rudiment of next year's leaf, the leaf of the current year, and the remains of the old leaf-stalks of past years, will be found at successive intervals behind the growing-point, and placed on either side alternately. The mature leaf may attain a very large size. Upon either side of the leaf-stalk *pinnæ* are arranged—the lower ones very large, and subdivided into *pinnules.* These in their turn are *pinnatifid*—that is, excavated at the margins by fairly deep notches.

Anatomy and Histology.—In both the Male Fern and the Bracken the leaf is very slowly developed, and continues for a long time to grow in length by means of a wedge-shaped apical-cell. The pinnæ are to be regarded as branches, which commence as bulgings of the meristem below the growing-point.

The structure of the leaf-stalk closely resembles that of the stem; but the sclerenchyma is much reduced in quantity, and the more external cells are green, owing to the presence of chlorophyll-granules. The flattened pinnæ and pinnules possess upper and lower layers of epidermis (Fig. 18), the cells of which contain chlorophyll. In the lower epidermis are numerous *stomata*, each of which is bounded by two curved *guard-cells.* The vascular bundles, or "veins," of the leaf are arranged pinnately, lateral branches being given off obliquely from a central midrib, which fork as they run towards the margin. In other words, the *venation* is pinnate.

The vascular bundle of the midrib in cross-section is seen to be somewhat *collateral*—that is, the xylem and phloem tend to lie side by side.

The ground-tissue, or *mesophyll*, is made up of short, thin-walled parenchymatous cells, which often possess short processes. These cells are united together so as to leave intercellular *air-spaces* between them. These spaces are larger on the lower side of the leaf, where the stomata open into them. The mesophyll cells contain numerous chlorophyll granules.

(3.) **The Root.**—*External Characters.*—The roots (Fig. 16, *r*, *r'*) are slender brown structures given off from the sides of the rhizome and bases of the leaf-stalks in the Bracken, and growing out from the bases of the leaf-stalks in the Male Fern. They branch *monopodially*—*i.e.*, the main axis does not fork, but gives off side-branches.

Histology.—(*a.*) **Meristem.**—The end of each root grows by means of an apical-cell, in the form of a three-sided pyramid, like the stem of the Male Fern. But in the stem *segmental cells* are only cut off from the *sides* of the pyramid, here they are cut off from the *base* also, to form by sub-division the *root-cap.* This is a protective sheath for the growing-point, and is made up of several layers.

(*b.*) **Epidermis.**—This is not well seen except in the younger parts of the roots. It possesses no stomata, but its cells grow out into numerous root-hairs (*see below*).

(*c.*) **Vascular Bundles.**—A central *vascular cylinder* is present which possesses the histological elements found in the stem. The Xylem and Phloem are, however, arranged *radially*, two masses of the former alternating with two of the latter. This is best seen in young roots, for later on the two patches of Xylem have grown towards, and united in, the centre. The root-branches grow out from the bundle-sheath opposite the masses of Xylem, and force their way to the exterior by rupture of the ground-tissue and epidermis. This mode of origin is called *endogenous*. The main roots arise from the stem in the same way.

(*d.*) **Ground Tissue.**—A firm ring of *sclerenchyma* is developed in this, which surrounds the vascular bundle.

The essential morphological characters of stem, leaf, and trichome have already (pp. 35 and 31) been given, and those of the *root* may now be stated as (1) *endogenous* origin, (2) presence of a *root-cap*, (3) non-possession of leaves, (4) descending growth.

(4.) **The Trichome.**—Not only the roots, but the underground parts of the stem possess true *root-hairs*, delicate unicellular tubes. Hairs in the form of cell-rows are common in different parts of the plant, especially in the growing points of the stem, in the Bracken.

The apical bud of the Male Fern is thickly covered with flattened brown plates, *ramenta*, which are epidermal outgrowths. These are also found on the axes of the leaves. The *sporangia* also come under the category of trichomes.

2. Reproductive Organs (Fig. 16, B, C, and Fig. 18).—These are minute, stalked spore-cases or *sporangia*, which are mature in autumn, and are then aggregated into brown patches, *sori*, on the backs of the leaves. The sori of the Male Fern are small and rounded. They are arranged on the back of each pinnule in two rows, one on either side of the midrib, and are placed in the course of the "veins." Each sorus is covered by a kidney-shaped flap, the *indusium* (Fig. 18, *i*), which is attached by a stalk to the pinna, and being a special outgrowth is termed a "true" indusium. The sori in the Bracken are placed in streaks along the margins of the backs of the pinnules. There are no true indusia, but the edges of the pinnules are bent sharply over to form "false" indusia.

The arrangement of sori is of great importance in classification. In two other common ferns, the Hart's-tongue (*Scolopendrium vulgare*) and common Polypody (*Polypodium vulgare*), the sori

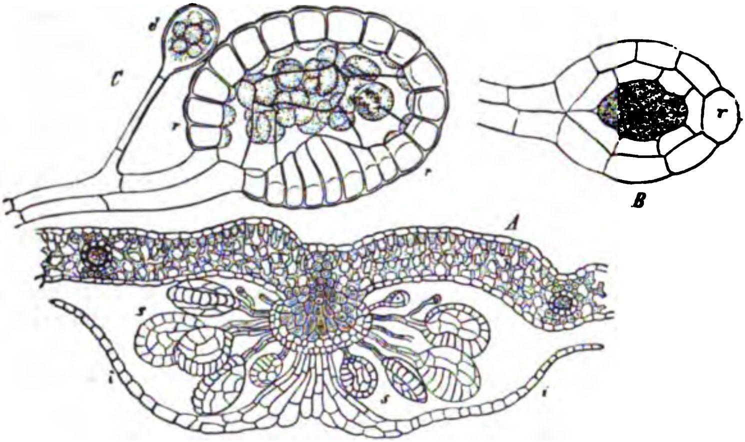

Fig. 18.—TRANSVERSE SECTION, SORUS OF MALE FERN, much enlarged (from *Sachs*).—A, Shows group of sporangia, *s*, various ages, growing from placenta; *ii*, indusium. B, Young sporangium showing wall of capsule (*r*), tapetum, and commencing mother-cells. C, Mature sporangium; *r*, annulus; *d*, gland.

are respectively broadish streaks placed obliquely on either side of the midrib with a flap-like indusium on both sides—and like those of the Male Fern, but without indusia.

A *sporangium* (*s*) consists of a long *stalk* made up of two or three rows of cells and a biconvex *capsule*. The sides of this are formed by a single layer of thin-walled, flattened cells, while its thickened margin is made up of a row of cells, with thickened walls, coloured bright brown in mature specimens. The *ring* (*r*), as this margin is termed, is not complete, being interrupted by the junction of the stalk. It is transversely ribbed, owing to the projection of the thickened partitions between its cells. This is especially marked on one side, the cells of the other being relatively broad and weak.

The sporangia of a Male Fern sorus are attached to a small projection, the *placenta*, on the under side of the pinna (Fig. 18, A), from which they radiate in all directions. Vascular elements enter into the placenta, and the indusium (*i*) is attached to it.

Each sporangium arises as an outgrowth from an epidermal cell. This outgrowth is first separated by a cell-wall from the epidermal cell, and is then divided by a transverse partition into a basal stalk-cell, and a terminal capsule-cell. The former by its division produces the stalk, the latter becomes the capsule. After enlarging, four oblique walls are formed, which divide the capsule-cell into four superficial flattened wall-cells, and an internal tetrahedral cell, the *archesporium* (Fig. 18, A, topmost sporangium on the right). The wall-cells form the wall, including the ring, and from the sides of the archesporium flat cells are split off, which divide to produce a layer known as the *tapetum*, while its remaining part undergoes continued bipartition to produce sixteen spore-mother-cells (B, shows wall (*r*), tapetum, and four mother-cells). Each mother-cell divides to produce four spores, and by the disintegration of the tapetum, which furnishes nutriment to them, the spores in the mature capsule lie loosely within the wall (*c*).

II. OOPHYTE.—The sexual generation is a small, green, flattened body, not differentiated into stem, leaf, and root, and receiving therefore the name of **prothallus.**

1. Vegetative Organs.—The plant-body is somewhat kidney-shaped, and the anterior end is marked by a deep notch, at the bottom of which is the growing-point, where, in young examples, a wedge-shaped *apical-cell* is present. The prothallus rests somewhat obliquely upon the soil, to which it is attached by numerous simple tubular root-hairs growing out from its under surface. The cells exhibit no differentiation into tissues. They are polyhedral, and their protoplasm contains numerous chlorophyll granules. The sides of the prothallus are only one-cell thick, but there is a central area, the *cushion*, which is thicker than this. It is from the superficial cells of the cushion that the root-hairs grow out.

2. Reproductive Organs.—These are found on the under side of the prothallus.

(1.) **Male Organs** (Fig. 19).—These are minute, more or less hemispherical *antheridia*, situated posteriorly and laterally. Each antheridium (I.) consists of a wall, within which are spermatozoid-mother-cells. In each of these a spermatozoid is formed

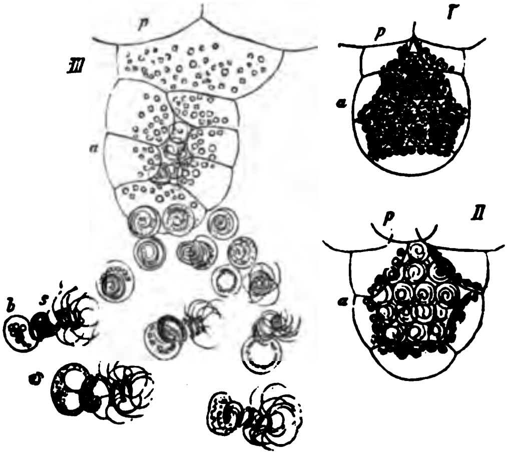

Fig. 19.—ANTHERIDIA OF FERN (× 550), (from *Sachs*).—I.-III., successive stages; *p*, cells of prothallus; *a*, antheridium; *s*, spermatozoids; *b*, vesicles attached to ditto.

(II. and III.), which is coiled spirally several times. To the anterior coils numerous flagella are attached and a delicate vesicle (*b*), representing part of the mother-cell's protoplasm, often clings to the hinder end. Each antheridium is developed as an outgrowth of a superficial cell of the prothallus, from which it is separated off by a transverse wall, after which, enlarging, it is divided into an external cellular wall and an internal cell, which divides into the spermatozoid-mother-cells. Old antheridia have brown walls.

(2.) **Female Organs** (Fig. 20).—These are *archegonia*, placed on the cushion, near the anterior end.

Each archegonium possesses a short curved *neck* (*h*), made up of four rows of cells (D). The terminal four are the *lid-cells*, which are closely apposed in the immature archegonium (A, B, C).

There is no distinct *venter*. The *oosphere* is surrounded by the tissue of the cushion. A *ventral-canal-cell* and an elongated *neck-canal-cell* are present (*compare p.* 47), the latter possessing several nuclei in a row. Old archegonia may be distinguished by their brown colour.

The archegonia are developed from superficial cells of the cushion. Each of these projects outwards, and is then divided by two walls parallel to the surface of the prothallus into three cells—internal, middle, and external. The fate of these is best shown in a tabular form.

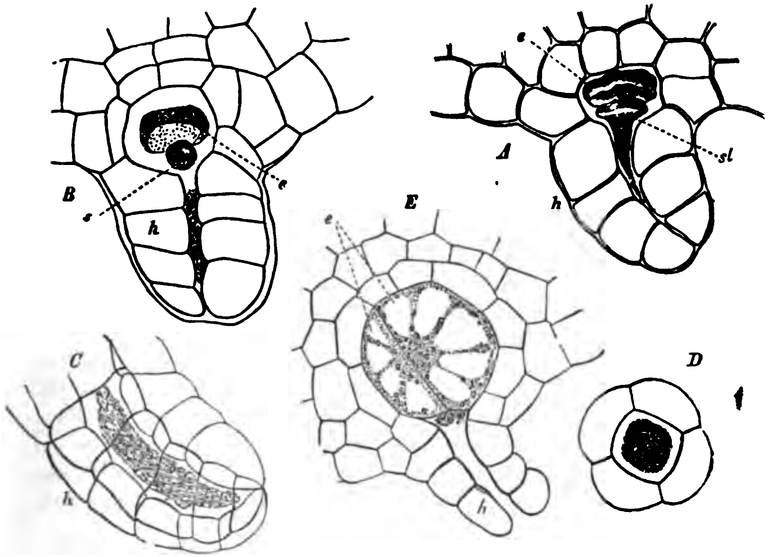

Fig. 20.—Archegonia of Fern (× 800), (from *Sachs*).—A, B, C, E, In longitudinal optical section; D, in transverse optical section; A, B, C, before, E after fertilization; *h*, neck; *st*, mass of mucilage; *e*, oosphere; E*e*, two-celled embryo—the basal wall has been formed.

From division of superficial cell.	I. Internal Cell	Divides up into cells which surround the oosphere, and form with tissue of cushion the wall of venter.
	II. Middle Cell	1. *Neck-canal-cell,*—forces its way between cells of neck. 2. *Central cell.*—Pinches off (*a.*) Ventral canal cell; and becomes (*b.*) oosphere.
	III. External Cell	Divides into rosette of four cells which produce four cell-rows of neck.

PHYSIOLOGY.

For 1. **Nutrition**, and 2. **Destructive Metabolism**, *see Chap. VI.*

3. **Reproduction.**—The *sporophyte* exhibits **asexual reproduction**, spores being produced which develop into oophytes.

Apospory occasionally occurs in Ferns—that is, oophytes are developed *vegetatively* from the sporophyte as outgrowths from the ends of the pinnæ, or from the stalks and capsule-walls of sporangia.

Vegetative reproduction also occurs in some ferns for the formation of new *Sporophytes* which, as in *Asplenium bulbiferum*, a common garden plant, grow out as buds from the leaves.

The *oophyte* reproduces **sexually** to form new sporophytes. The wall-cells of the *antheridia* swell up by imbibition of water, and the consequent pressure on the contents effects a rupture by which the spermatozoids are liberated (Fig. 19, III.) As in the Moss (*compare p.* 48), the canal-cells of the archegonium swell up and become mucilaginous, forcing apart the lid-cells. In this case the attracting principle in the extruded mucilage is some compound of malic acid. One or more spermatozoids force their way down the neck of the archegonium and fertilize the oosphere, which becomes an *oospore.* The oosphere presents as in *Chara* a clear *receptive spot.*

Apogamy sometimes occurs—that is, sporophytes are developed *vegetatively* from the prothalli.

4. **Contractility**, and 5. **Irritability** and **Spontaneity** are possessed by the spermatozoids.

DEVELOPMENT.

1. **Sporophyte.**—In the oospore, upper, lower, anterior, and posterior sides can be distinguished, determined by the corresponding regions of the prothallus. The lower side of the embryo *faces*, therefore, the *neck* of the archegonium.

The oospore first forms a cellulose coating, and is then divided into anterior and posterior hemispheres, by a *basal wall* parallel to the axis of the archegonium (Fig. 20, E).

The terms *hemisphere*, *quadrant*, and *octant* in the following account are not used in the exact sense—*e.g.*, it is not meant that the hemispheres are exactly equal in size.

The *anterior* hemisphere, originating as it does the *ascending* stem and leaves, is called the **epibasal** half of the embryo. The *posterior* hemisphere produces the *descending* root, and is therefore termed the **hypobasal** half.

The basal wall is followed by a *transverse* wall at right angles to it, and parallel to the plane of the prothallus. This divides the embryo into *quadrants*, which are subdivided into *octants*, by a third *median* wall, perpendicular to both the preceding. The octants develop as follows:—

Epibasal	Upper.	1. *Stem-octant.*		Growing point of stem.
		2. [*Octant.*]		Only a few hairs.
	Lower.	3. *Octant,*	leaf-quadrant.	*Cotyledon* or rudimentary 1st leaf.
		4. *Octant,*		
Hypobasal.	Upper.	5. *Root octant.* (Diametrically opposite to 1.)		First *root.*
		6. [*Octant.*]		Only a few hairs.
	Lower.	7. *Octant,*	foot-quadrant.	*Foot,* an embryonic organ.
		8. *Octant,*		

The young sporophyte remains for some time connected with the oophyte, deriving nutriment from it by means of the *foot*, a projection which grows into the cushion. The archegonium also continues to grow for some time. The ascending axis of the young fern-plant curves upwards round the notch of the prothallus. The prothallus ultimately dies, and the sporophyte commences a separate existence.

2. Oophyte.—The spores developed on the sporophyte soon germinate if kept warm and moist. The exospore is ruptured, and two delicate filaments covered by the endospore protrude. One elongates, and becomes first a row and then a plate of chlorophyll-bearing cells; the other is the first root-hair. The plate continues to grow by a wedge-shaped apical-cell, and the adult form is gradually assumed.

CHAPTER V.—GYMNOSPERMS.

§ 11. PINUS (The Fir).

The plants belonging to this genus are trees inhabiting the Northern hemisphere, within which they have a wide distribution. The only indigenous species is *Pinus sylvestris*, the Scotch Fir.

MORPHOLOGY.

A well-marked alternation of generations is here present, but the *sporophyte* is far larger and better developed than the *oophyte*, which is minute and, at least in part, intimately connected with the sporophyte. In order to understand the state of things existing in Pinus, it will be necessary to consider the nature of the oophyte in certain forms intermediate between the Fern and Pinus. It has been seen that in the Fern, the sporophyte produces *spores* in *sporangia;* each spore is capable of developing into a bisexual prothallus or oophyte. There are, however, some plants more complex in structure than the Fern (but simpler than Pinus), such as *Selaginella*, a common green-house form, in which the sporophyte bears male and female spores—*microspores* and *macrospores* (so named because the former are small and the latter large), contained in *microsporangia* and *macrosporangia.* Within the microspore is developed a very rudimentary *male prothallus*, which originates one or more *antheridia*, producing motile *spermatozoids* somewhat resembling those of the Fern. In the macrospore a rather larger (but still very small) *female prothallus* is formed, in which one or more *archegonia* arise. These are exposed to the exterior by the bursting of the coats of the macrospore, and are fertilized by the spermatozoids in the usual way.

Such micro- and macrospores, in which male and female prothalli are developed, are found in Pinus, but they are here still more rudimentary.

I. SPOROPHYTE.—Pinus, when mature, is a tree of large size, and it is well differentiated into stem, leaves, and roots.

1. Vegetative Organs.—(1.) The Stem.—*External Characters.*—

A main stem or *trunk* is distinguishable, upon which are developed lateral branches, which appear to arise in whorls. These branches bear still smaller ones in the same way, and so on. The entire branch system is *racemose* (*see p.* 94).

The trunk and old branches are covered with a fissured *bark*, while the youngest shoots are green. If a branch of Pinus is taken in autumn, the growths of successive years can readily be recognized, as they are bounded by false whorls of axes. The growth of the current year is terminated by a large bud, around which are a number of smaller lateral buds. In the following spring, this terminal bud will develop into a new shoot, the lateral buds, at the same time, growing into side-branches, and hence being termed buds of *unlimited growth*, as they terminate in growing-points which may cause elongation to an indefinite extent.

Anatomy.—The three systems of tissue—epidermis, vascular bundles, and ground tissue, are well differentiated. The *epidermis* is only present in young branches, being afterwards replaced by layers of *cork*.

The *vascular bundles* have the following arrangement, which is typical of Pinus and Dicotyledons (*see p.* 78, Fig. 24, D). They are *common*, that is to say, the bundles from the leaves run into the stem, and take a downward course within it, almost at once, parallel to other bundles. That part of a common bundle which runs within the stem is termed a *leaf-trace*. At the nodes, more or less branching and union of bundles take place.

The *ground-tissue* can be divided into the *pith* within the bundles, and the *cortex* outside of them.

The stems exhibit *secondary increase in thickness*, leading to the formation of *annual rings* of wood, readily seen in cross sections of the trunk, &c., and by which the age can be approximately determined.

Histology.—(*a.*) **Growing Point.**—The end of each ultimate ramification of the stem is occupied by a mass of meristem; there is not, however, as in the fern, a single apical-cell from which all the tissue arises, but a group of such cells. These, before passing over into permanent tissues, are differentiated into definite layers, from which those tissues arise. These layers may be termed *dermatogen*, or formative layer for the epidermis; *periblem*, or formative layer for the cortex; and *plerome*, or formative layer for the vascular bundles and pith. The *apical-* or *initial-cells* occupy in this case the extreme apex, a little below which the dermatogen forms a superficial layer one-cell thick; beneath this is the periblem several cells thick, the centre of the stem being occupied by the plerome cylinder. A little lower still, the latter can be divided into an external part, the *procambium*, from which the bundles are produced, and an internal part originating the *pith*. There is no distinct boundary between these meristem layers and the permanent tissues, but a gradual and insensible gradation takes place.

(*b.*) **Epidermis.**—This is present in the young stem, and is made up of a single layer of cells, with cuticularized walls, the external ones being most thickened, and forming the cuticle.

(*c.*) **Vascular Bundles.**—In the bud these form a ring, the different bundles of which are isolated. Between them are strips of ground-tissue, seen in cross-section, which connect the pith with the cortex, and are termed *primary medullary rays*. Each bundle is *collateral*, containing xylem and phloem, which are placed upon the same radius, the former being internal. They are termed *primary xylem* and *primary phloem*. The bundles are also *open*—*i.e.*, they are capable of further development, owing to the presence of a meristem layer—the *cambium*—placed between the xylem and phloem, and effecting their increase. The innermost and first-formed part (*protoxylem*) of the primary xylem is composed of spiral and annular *tracheides*. The primary phloem contains *sieve-tubes*, upon the radial side-walls of which are circular sieve-plates, and also phloem parenchyma. The cells of the cambium are elongated and thin-walled, and they contain abundant protoplasm. In older stems *secondary* xylem and phloem are present, formed by the agency of the cambium. This secondary increase is explained in Fig. 21. A shows six isolated bundles in the young stem, similar to those described above. They are separated from one another by the primary medullary rays. In B, cambium has been formed in the interspaces between the bundles. This is *interfascicular* cambium (*ic*), which, together with the cambium in the bundles, makes up a complete *cambium ring*, the cells of which are continually dividing to produce secondary xylem on the inside of the ring, and secondary phloem on the outside of the ring. These are produced *all round*—not only within the area of the original bundles, but between them. In C this process has gone on for some time. The position of the primary xylem is indicated at *x,x,x;* outside of this comes the secondary xylem, part of it (*fh*) having been formed by the fascicular portion (*fc*), and part (*ifh*) by the interfascicular portion (*ic*) of the cambium ring. External to this ring, the secondary phloem is placed, and, like the secondary xylem, this may be

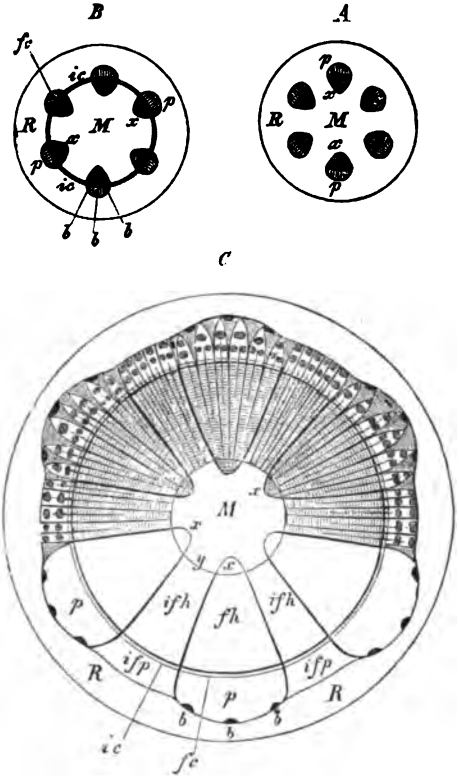

Fig. 21.—Diagram of Secondary Increase in Thickness of Stem (from *Sachs*).—A, Bundles isolated. B, Interfascicular cambium formed. C, Stem much thickened. *x*, Primary xylem; *p* in A and B, primary phloem; *i.c*, interfascicular cambium; *fh* and *ifh*, secondary xylem; *p* and *ifp*, secondary phloem in C, where *b,b,b* marks position of primary phloem. M, Pith. R, Cortex.

divided into fascicular and interfascicular (*p* and *ifp*), produced by the corresponding parts of the cambium ring. The position of the protophloem is indicated at *b,b,b.* In actual stems the secondary elements are exactly the same, whether formed by fascicular or interfascicular cambium. Numerous *medullary rays*

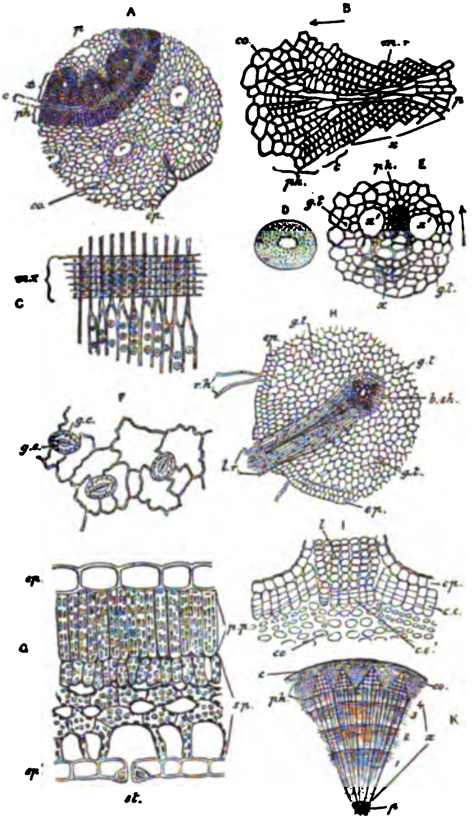

Fig. 22.—Histology of the Vegetative Organs, various scales (G I K after *Prantl*).—A, Part of transverse section of current year's *Pinus* stem. B, part of same more enlarged. *ep*, Epidermis; *x*, xylem; *ph*, phloem; *c*, cambium; *p*, pith; *co*, cortex; *rr*, resin passages; *mr*, medullary rays. C, Small piece of radial section of *Pinus* stem, to show pitted tracheides. *m.r*, Medullary ray. The arrows point to outside.

may also be distinguished, indicated by dark lines in the figure. They are narrow plates of tissue, extending radially, and either running right through from pith to cortex, when they are *primary*, or only part way, when they are *secondary*. The nature of medullary rays is shown in Fig. 24. Before returning to Pinus it will be well to mention that longitudinal sections are either *radial*—*i.e.*, corresponding with a radius, or *tangential*, *i.e.*, as near as may be perpendicular to this. The piece of wood drawn in Fig. 24 is bounded by a tangential section at T, and radial sections laterally.

In a cross section of Pinus stem, developed in the current year (Fig. 22, A and B), a complete vascular ring has been formed by the activity of the cambium ring (Fig. 22, A). The **Xylem** (*x*) is much thicker than the phloem, and the position of the primary xylem is indicated by rounded projections into the pith (*p*). With the exception of the protoxylem (in which *spiral* and *annular tracheides* are present), the xylem is mainly composed of tracheides with *bordered pits* (Fig. 22, C). The cells of these elements are thickened and lignified, new layers having been added on their inner sides by the protoplasm which they once contained. But, as in the scalariform elements of the fern, the thickening has not been uniform, and thin places are left as *pits*. They are "bordered," because the mouths of the pits are narrower than their floors, and the two are seen together by transparency as concentric circles. Pits are only found on the radial walls, and those of adjacent tracheides exactly correspond, as in the fern, each pair being floored by a common *pit-membrane*, which represents part of the original unthickened party-wall between the tracheides. This is usually pushed on one side. Longitudinal intercellular spaces, *resin-passages*, are also seen in the Xylem (A and B). These are lined by small cells, which excrete resin into their cavities. The **Phloem** is much thinner (Fig. 22, A, *ph*), and is composed of *sieve-tubes*, with circular sieve plates on their radial walls, and *phloem parenchyma*, the cells of which are arranged in radial rows. The **Cambium*** is made up of thin-walled cells, elongated, and containing abundant protoplasm. They constantly divide tangentially to produce cells which pass over into the Xylem on the one hand, and the Phloem on the other. Hence the tendency of the Phloem-elements (and also for those of the Xylem) to arrange themselves in radial rows. This is shown in Fig. 22, B. The cambium cells also divide radially, and thus their ring increases in diameter to keep pace with the thickening Xylem. In older stems the Xylem is very much thicker than the Phloem, and makes up the "wood." Annual rings may be distinguished in this, owing to the fact that spring wood is much more open in texture than the wood formed during the preceding autumn, terminating the year's growth. Where, as in tropical climates, growth is continuous, the secondary elements are at all times similar, and no annual rings can be discerned. Annual rings are shown at K, Fig. 22, in the case of a four-year-old twig of Lime. The phloem is developed much less than the xylem, by the growth of which it is very much distorted, and consequently annual rings are only exhibited by it in a very imperfect manner. The *medullary rays* are composed of parenchyma, the cells of which in the young stem possess cellulose walls, but in older stems may be thickened, lignified, and pitted. Their vertical extent is small (*see* Fig. 24), and their elements are arranged, as seen in radial section (Fig. 22, C), like the courses of bricks in a wall. When cut across—*i.e.*, as in a tangential section—they are more or less lenticular in appearance (Fig. 24).

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* *Cambium* is an example of *secondary* meristem—*i.e.*, it occurs in layers intercalated among permanent tissue. *Primary* meristem makes up the whole of young organs and growing-points.

(*d.*) **Ground Tissue.**—The pith is composed of parenchyma, the cells of which possess in the young stem thickened cellulose walls, but in older stems many are modified as in the medullary rays. In the young stem (Fig. 22, A), the cells of the cortex are parenchymatous, with thick cellulose walls and chlorophyll-containing protoplasm. Resin passages occur (*rrr*) like (but much larger than) those in the xylem. As secondary increase in thickness takes place, the epidermis is stretched and finally ruptured. Its place is taken by **cork**. A layer of cells near the periphery becomes meristematic to form a *cork cambium*, from which *cork-cells* are cut off on the outside. A continuation of the process leads to the formation of **bark**, pieces of which are being continually stripped off as the stem grows (*see p.* 83 and Fig. 27). This process of scaling-off commences in *Pinus sylvestris* when from eight to ten years old. In young stems, patches of *sclerenchyma*, with thick and lignified walls, occur here and there beneath the epidermis.

(2.) **The Leaf.**—*External Characters.*—Two kinds of leaves are found in Pinus,—scale-leaves, which are the only sort borne by the older axes, and foliage-leaves, found on the branches belonging to the current year.

(*a.*) The *scale-leaves* are brown and membranous at their tips, but succulent at their bases. In a current year's stem, buds are produced in their axils. These buds are, firstly, buds of *unlimited* growth, several of which are found near the end of the stem and grow into new lateral axes, and, secondly, buds of *limited* growth, each of which produces two foliage-leaves at the commencement of the year.

(*b.*) The *foliage-leaves* are borne in pairs on an extremely short common stem. Each of them is elongated and needle-like, one side (the upper) being flat, the other (the under) curved. They are green in colour.

Anatomy and Histology.—*a.* **Epidermis.**—This in the foliage-leaves is made up of cells, the external walls of which are much thickened and cuticularized, their outer part forming a distinct cuticle. Numerous *stomata* are present both in the upper and under sides. Each of them is bounded by two curved *guard-cells* (*compare p.* 91), deeply sunk in the epidermis.

b. A single **vascular bundle** enters each leaf, and at once divides into two, which run side by side, their xylem uppermost. The bundle-elements resemble those of the stem. They are surrounded by colourless parenchyma, the outermost layer of which forms a *bundle-sheath.*

c. **Ground Tissue or Mesophyll.**—This is mainly formed by parenchymatous cells, the protoplasm of which contains chlorophyll, while the cellulose walls are curiously infolded.

d. **Resin-passages** are present similar to those of the stem, and surrounded by fibrous sclerenchyma, a layer of which also underlies the epidermis, except where stomata occur.

(3.) **The Root.**—*External Characters.*—A main or *tap-root* is present, which is a direct prolongation of the *radicle* of the embryo (*see p.* 75). From this lateral roots are given off, which again bear smaller roots, and so on.

Anatomy and Histology.—(*a.*) **Growing Point.**—Each root-apex contains a distinct *plerome,* the end of which is rounded off and formed by a small group of *initial-cells.* This is surrounded by the *periblem,* made up of several layers, each of which possesses a group of initial-cells lying over the end of the plerome. There is no *dermatogen*, but the outer layers of the periblem become loosened to form a protective *root-cap* for the growing-point.

(*b.*) **Epidermis.**—An indistinct layer of this is present upon younger roots.

(*c.*) **Vascular Bundles.**—In the centre of the young root a *vascular cylinder* is present, which is surrounded by a *bundle sheath*, one-cell-thick, within which is a *pericambium*, two or three cells thick. Internal to this, again, are from three to six masses of *primary Xylem*, alternating with as many masses of *primary Phloem.* In older roots secondary increase in thickness takes place as in the stem. This is effected by the formation of a *cambium*, which commences internally to the *primary Phloem* groups, in the parenchyma there found. These masses of cambium ultimately become connected with similar masses developed on the outside of the primary Xylem groups to form a continuous cambium ring, which, of course, is at first curved in and out in accordance with its mode of development, but ultimately comes to assume the usual form. It develops secondary Xylem and Phloem as in the stem, and sections of old roots are very similar to sections of old stems. For the arrangement of the tissues in the young root compare Fig. 27, H.

The *pericambium* is of great importance. It produces in old roots a *cork cambium* (*compare p.* 81) which gives rise to layers of cork, and lateral roots also originate from it opposite the masses of xylem (Compare Fig. 27, H). The xylem and phloem contain the same elements as in the stem.

(*d.*) **Ground Tissue.**—This forms in the young root a broad *cortex*, between the epidermis and vascular cylinder. In the old roots, the bundle-sheath and everything external to it are thrown off, or remain as withered remnants. The cork formed by the pericambium then serves as a protective investment.

(4.) **The Trichome.**—Unrepresented.

2. **Reproductive Organs** (Fig. 23).—*External Characters.*—These are of two kinds, male and female, found respectively in male and female *flowers.* The flower may be defined as,—"an axis bearing *sporophylls.*"

(1.) **Male Flowers.**—These are specially modified lateral buds, aggregated together near the termination of a stem to form an *inflorescence* (A). The end of the same stem bears foliage-leaves.

The male flower is a collection of *male sporophylls*, or *stamens.* Each of these is a broad, scale-like structure (B), attached by a short stalk or *filament* (*f*). The rest of it is the *anther*, on the lower surface of which are two oval swellings, the *pollen-sacs* (microsporangia, *p.s*). Within these is formed *pollen*, which escapes in June as a yellow dust by the *dehiscence*, *i.e.*, splitting open, of each pollen-sac. This is effected by a longitudinal slit.

(2.) **Female Flowers.**—These are commonly known as *cones* (D), and are produced singly as modified lateral buds towards the apex of the branches of the current year. The young cone is made up of a large number of *female sporophylls* or *carpels.* These remain very inconspicuous; but from the axil of each a relatively immense outgrowth is developed, which may be termed

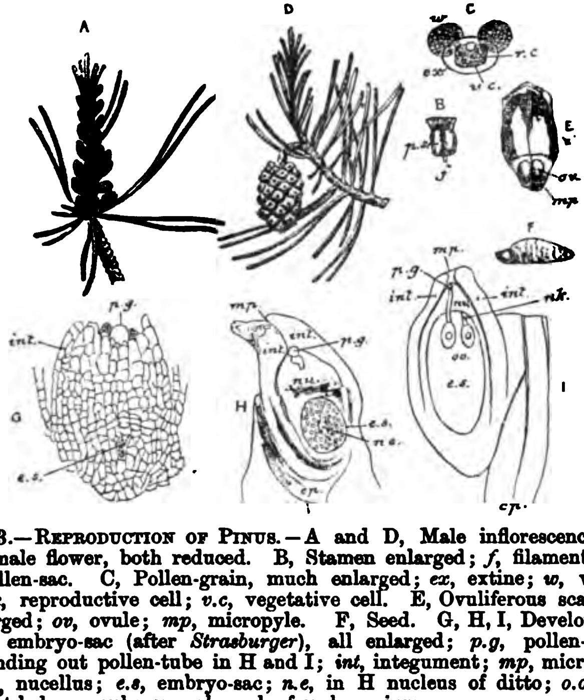

Fig. 23.—REPRODUCTION OF PINUS.—A and D, Male inflorescence and female flower, both reduced. B, Stamen enlarged; *f*, filament; *p.s*, pollen-sac. C, Pollen-grain, much enlarged; *ex*, extine; *w*, wings; *r.c*, reproductive cell; *v.c*, vegetative cell. E, Ovuliferous scale enlarged; *ov*, ovule; *mp*, micropyle. F, Seed. G, H, I, Development of embryo-sac (after *Strasburger*), all enlarged; *p.g*, pollen-grain, sending out pollen-tube in H and I; *int*, integument; *mp*, micropyle: *nu*, nucellus; *e.s*, embryo-sac; *n.e*, in H nucleus of ditto; *o.o*, in I just below oospheres; *nk*, neck of archegonium.

an *ovuliferous scale*. The ends of these appear as rhomboidal areas upon the surface of the older cone (D). If an ovuliferous scale belonging to a cone of the second year is removed (E), two small oval bodies will be seen near its base. These are *ovules* (macrosporangia, *ov*),

Anatomy and Histology.—Each *pollen-sac* arises as an outgrowth from the stamen, partly composed of epidermis, and partly of the underlying tissue. Within it is contained a large cell belonging to the latter, and known as the *archesporium*. From this are formed a number of *pollen-mother-cells*, each of which divides into four *pollen-grains*. Inside the wall of the pollen-sac, there is at first a *tapetum* as in the fern. This, however, breaks up before the pollen-grains are ripe, so that these lie free within the sac. The mature *pollen-grain* (C) is invested by a delicate *intine* (endospore), external to which is a firmer cuticularized *extine* (exospore) produced into two lateral air-containing bladders or *wings* (*ex* and *w*). The *ovule* arises as an outgrowth (from the ovuliferous scale) made up of epidermis and deeper cells, the external part of which becomes differentiated into an *integument* (*int.* in G, H, I). At one point this is incomplete, an opening, the *micropyle* (*mp*), being present, which lies at the lower end of the ovule (E). The internal tissue is known as the *nucellus* (*nu*), within which during the first year, a larger cell, the *embryo-sac* (macrospore) appears (*e.s*). The further development of this will be considered under the oophyte.

II. OOPHYTE (Fig. 23).—(1.) **Male Prothallus.**—Within the pollen-grain two cells are formed (C)—a larger *reproductive cell* (*r.c*), and a smaller *vegetative cell* (*v.c*). The pollen-grain in this state is blown by the wind to the micropyle of the young ovule (G, *p.g*), and ultimately reaches the summit of the nucellus, into which a *pollen-tube* (*antheridium*) from the reproductive cell grows. The nucleus of this reproductive cell makes its way to the end of the pollen-tube, where it divides into a number of smaller nuclei, which are equivalent to *spermatozoids*.

(2.) **Female Prothallus.**—This is formed within the embryo-sac as a mass of delicate parenchyma, known as the *endosperm* (I, *e.s*). At the micropylar end of this, two rudimentary *archegonia* are formed, each of which consists of a small *neck* (*nk*), below which is a large oval *oosphere* (*oo*). The female prothallus is fully developed in cones of the second year.

PHYSIOLOGY.

(1.) **Nutrition**, and (2.) **Destructive Metabolism.**—*See pp.* 106 *and* 108.

(3.) **Reproduction.**—*Sporophyte.*—The **asexual** production of pollen-grains and embryo-sacs, &c., has been described above.

Oophyte.—This gives rise **sexually** to the sporophyte. The pollen-grains are produced in vast numbers, and *wind-pollination* occurs—*i.e.*, the pollen is blown to the micropyles of the ovules by the wind. The micropyle is at first widely open (Fig. 23, G), and the pollen-tube is developed as described. During the second year, when the archegonia are developed, the end of a pollen-tube enters the neck of each (Fig. 23, I), and one of the nuclei passes over and fuses with the oosphere, which is thus fertilized, and becomes an oospore.

DEVELOPMENT.

Sporophyte.—The *oospore* produces four embryos, each of which is placed on the end of a twisted thread, the *suspensor* (equivalent to the *foot* of the fern), and is turned away from the micropyle. In each ovule, however, only one embryo comes to maturity. In the third year's cone, this is found within a structure known as the **seed** (Fig. 23, F), resulting from the development of the ovule. It possesses an outer covering, *seed-coat* or *testa*, developed from the integument and produced into a membranous wing. Within this the *endosperm* is contained, and this again encloses the embryo, which possesses a root, or *radicle*, directed towards the micropyle, and at the other end a *plumule*, formed by the rudimentary stem, surrounded by the numerous first leaves, which are called *cotyledons*. The seed, within which the embryo can remain dormant for some time, is the most characteristic feature possessed by Pinus, and the plants above it in the scale.

Germination.—If placed under favourable external conditions (*see Chap. VI.*), the seed can germinate. The testa is burst by the swelling of the endosperm, and the embryo commences to develop, the radicle curving downwards, and the plumule elongating. The seed is carried up on the ends of the cotyledons, from which, however, it ultimately becomes detached. The subsequent development consists in the growth of the radicle into the tap-root of the adult, and the axis of the plumule into the main stem. The endosperm contains nutritive reserve-materials, upon which the embryo draws in the earlier stages of development (*see also p.* 107). The cotyledons remain attached to the seed till this supply is exhausted.

CHAPTER VI.—ANGIOSPERMS.

§ 12. THE TYPICAL FLOWERING-PLANT OR ANGIOSPERM.

Under this heading, the great bulk of common conspicuous plants are included. There is such a great variety in form and structure that it is thought advisable in this case to give a general outline of the group, illustrating the various points by, for the most part, common examples.

Angiospermous plants may be divided into two main sub-groups. These are (1) **Monocotyledons**, (2) **Dicotyledons**. Their characters will be seen in the sequel.

MORPHOLOGY.

Alternation of generations occurs, as in Pinus; and the asexual and sexual stages are similarly related, but in the latter still greater reduction has taken place.

I. SPOROPHYTE.—This varies very greatly in *size*, a circumstance which is mainly dependent on the fact that the duration of life varies within very wide limits. The terms *annual*, *biennial*, and *perennial* are used to express this, plants so named living one, two, or an indefinite number of years. It is evident that plants attaining any great size must be perennials. A rough classification may be made into *herbs*, *shrubs*, and *trees*, according to size, and these terms involve the structure as well. Shrubs and trees alone exhibit any marked development of wood, accompanied in Dicotyledons (and, more rarely, in Monocotyledons) by secondary increase in thickness.

1. Vegetative Organs.—As in preceding cases, it will be most convenient to deal with these under the headings—Stem, Leaf, Root, and Trichome.

(1.) **The Stem.**—*External Characters.*—The first-formed stem is found in the embryo—constituting, together with its terminal bud, the **plumule.** There may also be a part of the stem, **hypocotyl,** between the origins of the cotyledons and commencement of the radicle. This stem may be termed *primary*, and from it *secondary* stems are developed, usually in the axils of leaves, as branches. The forms of *branch-systems* will be dealt with under inflorescences (*p.* 94). The stem varies very much in **length.** In the case of trees, this may be very considerable; but on the other hand, by the suppression of the internodes, an extremely short axis may be produced. The leaves form in this case a crowded rosette on the short stem, and the flower-stalks appear to grow up from the roots, as, *e.g.*, in the Daisy and Dandelion.

The **thickness** also presents great differences, and with this goes *texture*, which may be *herbaceous* or *woody*. The relatively thick stems of perennials are termed *trunks*, *branches*, and *boughs*. These are generally more or less cylindrical, and usually solid. The herbaceous stems of annuals are called *stalks*. The lower part of a stem may be thickened, as in the Crocus, and form a *corm*, containing reserve material for the growth of a next year's plant, developed from a bud. Underground branches may also be thickened into receptacles for similar materials. These are *tubers*, bearing minute scale-like leaves, as, *e.g.*, in the Potato.

The thickness and firmness of the stem determine its relative position. If firm or thick, it may be *erect;* if not, *prostrate*, *creeping*, &c. A weak stem, however, by assuming a *climbing* habit, may ascend. Climbing plants are divided by Darwin into four groups. (*a.*) *Twining* forms (including the greatest number of examples), where, as in the Hop and Scarlet Runner, the stem grows spirally round a support. (*b.*) Plants with *irritable clasping organs*, in the form of *tendrils*. These may be modified leaves, branches, or flower-stalks. (*c.*) *Hook-climbers*, of which the common Cleavers (*Galium*) are examples, and (*d.*) *Root-Climbers*, as the Ivy. Creeping underground stems, *rhizomes*, may be thick or thin.

Thickening of a stem may be due to the excessive growth of succulent parenchymatous tissue, as in the Cacti. Plants of this sort are common in arid climates, as at the Cape and in Mexico.

The **shape** of herbaceous stems varies considerably, and they may be described as *angular, channelled, ribbed, &c.* In many cases, particularly in Grasses, the internodes are hollowed out, when the stem is said to be *fistular.* This favours the erect position, with expenditure of but little tissue, on the principle of the hollow column.

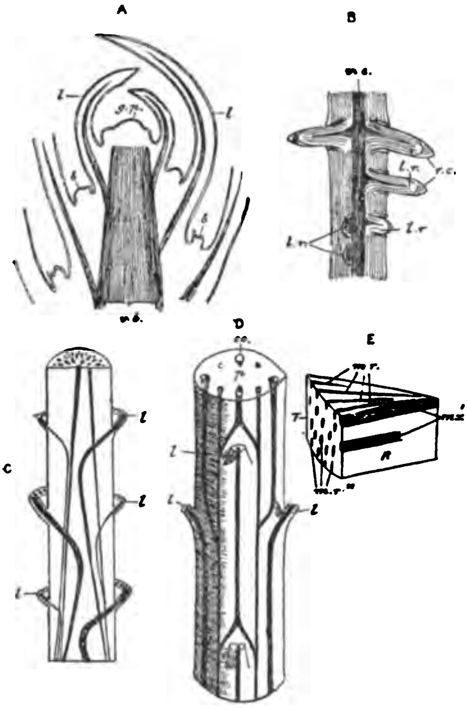

Fig. 24.—Diagrams of Anatomy of Vegetative Organs (after *Prantl*).—A, Relation of stem and leaves; *g.p*, growing-point; *v.b*, vascular bundles; *l*, leaves; *b*, axillary buds. B, Origin of lateral roots; *v.c*, vascular cylinder; *l.r*, lateral roots in various stages breaking through ground-tissue; *r.c*, root-caps. C, Course of bundles in Monocotyledon, and D, course of ditto in Dicotyledon; *l,l*, origins of leaves; *p*, pith, and *co*, cortex. E, Medullary rays traversing a piece of secondary xylem. R,T, Radial and tangential faces of piece; *m.r*, *m.r'*, *m.r''*, the rays as seen in transverse, radial, and tangential section.

Protective organs may be formed by modified branches, as in the spines of the Sloe.

Stems may become leaf-like, the true leaves being very minute. Such *phyllodes* are seen in the Butcher's Broom.

Anatomy.—In stems which, like those of the Dicotyledons, exhibit secondary increase, the **epidermis** is usually ruptured sooner or later. Its functions are assumed by *cork* (*see p.* 81) developed in the external ground-tissue. Owing to the formation of cork many Dicotyledons develop *bark*, as in Pinus.

The **vascular bundles** in Monocotyledons (Fig. 24, C) are scattered through the ground-tissue. They are all *common* to leaf and stem. The bundles from the leaves enter the stem and curve obliquely downwards and inwards, thickening in their progress. They then run outwards and downwards, at the same time becoming thinner, and finally unite with other bundles several internodes below the point where the stem was first entered.

The bundles of Dicotyledons (Fig. 24, D) are arranged more as in Pinus (*p.* 65), and a similar secondary increase in thickness may occur, giving rise to the formation of annual rings of xylem, &c.

Histology. — (*a.*) **Growing Point.**—In all cases, as in Pinus, a cell-group supplies the place of a single apical-cell. Taking the Scarlet Runner (Fig. 25) as an example, these cells produce—

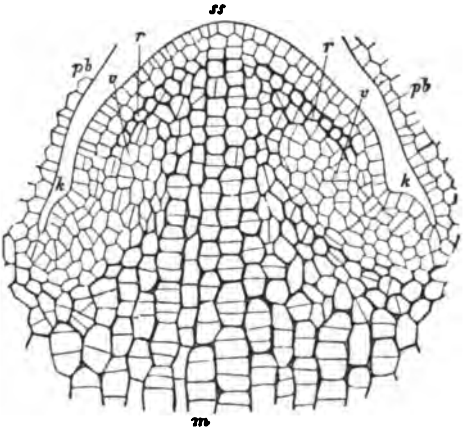

Fig. 25.—Section of Growing Point of Stem of Scarlet Runner (from *Sachs*).—*s.s*, Apex, covered by single layer of dermatogen, beneath which is periblem and internally plerome, *m* (with dark walls); *pb*, two first leaves; *k*, their axillary buds.

(1.) *Dermatogen.*—A single layer of cells, continued into the epidermis.

(2.) *Periblem.* — Several layers of cells which are continuous beneath, and merge into the primary cortex.

(3.) *Plerome.*—Consisting of an outer sheath, the *procambium*, which generates the vascular bundles, and a central core, from which the pith is developed.

(*b.*) **Epidermis.**—A single layer of small cells thickened externally to form a cuticle. Stomata may be present. The epidermal cells usually contain no chlorophyll.

(*c.*) **Vascular Bundles.**—These in Monocotyledons are *closed.* A cross-section of the stem of Asparagus (Fig. 27, D, E), for example, presents the cut ends of a large number of bundles.

The outlines of these are largest in the centre owing to the thickest part of a bundle being found where it curves inwards (*p.*78, Fig. 24). Each is *collateral* as in Pinus (*p.* 66).

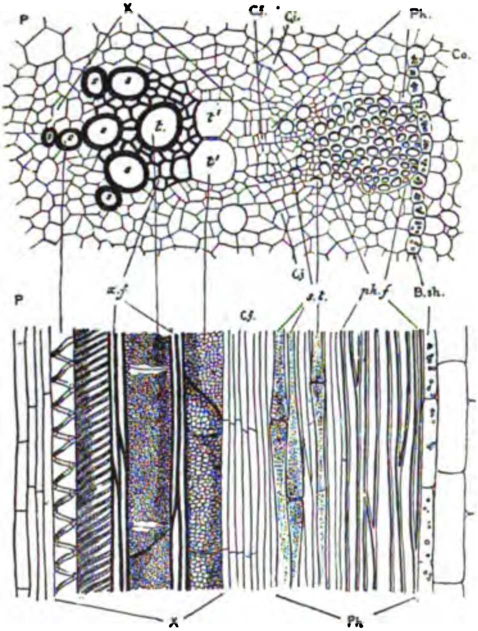

Fig. 26.—**Transverse and Radial Sections of Sunflower Stem** (after *Prantl*). *A single vascular bundle is shown.*—X, xylem; *ss*, spiral vessels; *tt*, pitted vessels; *t't'*, ditto in less advanced condition; *x.f*, xylem-fibres; *Ph*, phloem; *s.t*, sieve-tubes; *Ph.f*, phloem-fibres; *c.f*, fascicular cambium; *c.i*, interfascicular cambium; *b.sh*, bundle-sheath; *p*, pith; *co*, cortex.

The *Xylem* is somewhat U or V-shaped, with the apex directed towards the centre (*x*). This apex is the *protoxylem*, and is formed by *annular* and *spiral vessels*, with a small amount of *xylem* parenchyma. The limbs of the V contain larger *pitted vessels* (*x'*), the thickened walls of which exhibit scalariform pits. Around these are *tracheides* with lignified walls.

The *Phloem* (*ph*) occupies the interspace between the limbs of the V. It is mainly composed of *phloem parenchyma*, with a few *sieve-tubes*, and externally a small group of *phloem-fibres*. The sieve-tubes differ from the types previously seen in that the *sieve-plates*, instead of being lateral, form transverse perforated partitions between the ends of adjoining cells.

The ground-tissue becomes modified into *sclerenchyma* in the neighbourhood of each bundle, thus forming a kind of sheath.*

The bundles of Dicotyledons are *open* and *collateral* like those

* The *vascular bundle* + *fibrous sheath* = a "fibro-vascular bundle."

of Pinus, from which they differ mainly in the nature of the elements. The Xylem (Fig. 26, X) of an annual stem (as the Sunflower), consists internally of *spiral* and *annular vessels* (*s*), external to which are a number of *pitted vessels* (*t, t,*'). These have lignified walls, and so have the fusiform *xylem fibres* (*x.f*) also present. The remainder of the Xylem is formed by *Xylem parenchyma*, the cells of which may in some cases grow into the cavities of the vessels, and there form masses known as *thyloses.* Outside of the preceding elements comes the *cambium* (*c.f*), and then the *phloem* (*Ph.*), formed internally of *phloem parenchyma* with (*s.t*) *sieve-tubes* (*compare Asparagus*), and externally of *phloem-fibres* (*ph.f*). A *bundle-sheath* (*b.sh*) formed by a single layer of cells runs round the stem, and forms the outer boundaries of the bundles. It is also known as the *endodermis*, and exhibits (in transverse section) a dark shading on the radial walls, owing to the fact that these walls are not plane but wavy.

In stems showing secondary increase (Fig. 27, K), the *secondary xylem* and *secondary phloem* formed by the activity of the cambium ring contain the same elements as above; but the *protoxylem* alone contains spiral and annular vessels. As in Pinus, the phloem is much distorted in old stems by the increase of the xylem. *Medullary rays* are present (*compare p.* 69, and Fig. 24, E).

Aquatic stems are simpler than others in structure. They contain (in Dicotyledons—*e.g.*, *Hippuris*) a central vascular cylinder. It may also be noted that some stems exhibit an *anomalous* structure. In the Vegetable Marrow, Cucumber, &c., there are *two* masses of Phloem in each bundle, one external, and the other internal to the Xylem. Such bundles are termed *bicollateral.*

(*d.*) **Ground Tissue.**—This is typically composed of thin-walled parenchyma. In Dicotyledons a *pith* internal to the bundles can be distinguished from a *cortex* external to them. In Dicotyledonous stems exhibiting secondary increase, formation of *cork* takes place in the cortex, as in Pinus. A layer of meristem, the *cork-cambium* (Fig. 27, I, *c.c*) is produced, from which tabular, air-containing *cork-cells*, with thickened walls, are formed externally, and chlorophyll-bearing parenchyma—*phelloderm*, internally. (The latter is not present in 27, I.) The layers of cork thus formed protect the stem when the strained epidermis is cast off. They are collectively termed *periderm.* In Dicotyledons the place of stomata is then taken by *lenticels*, small areas, visible externally as oval projecting patches, in which the cork is made up of

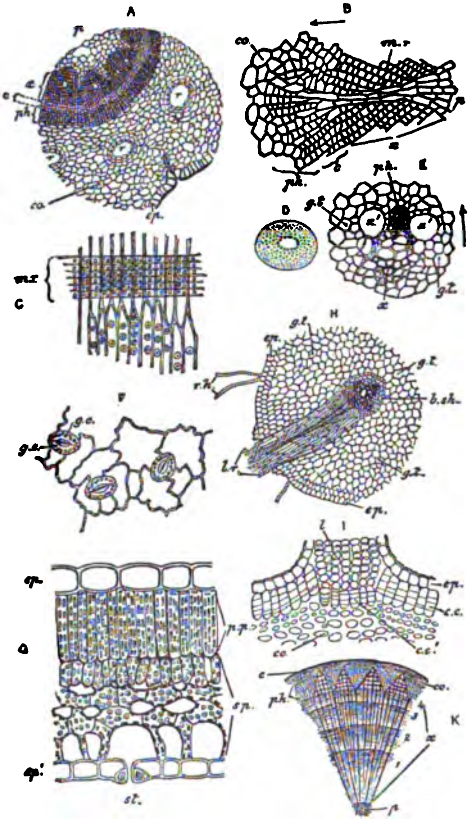

Fig. 27.—Histology of Vegetative Organs, various scales (G, I, K, *after Prantl*).—D, Transverse section of *Asparagus* stem, natural size. E, one bundle of same, enlarged; *x* and *x'*, oldest and youngest parts of xylem; *ph*, phloem; *g.t*, ground tissue—the arrow in this and B points to outside of stem. F, Lower epidermis from leaf of *Geranium; g.c*, guard cells of stomata. G, Transverse section of Beech leaf; *ep* and *ep'*, upper and lower epidermis; *pp*, palisade parenchyma; *sp*, spongy parenchyma; *st*, stomata. I, Section of lenticel of *Elder; ep*, epidermis; *l*, loose lenticel tissue; *c.c*, cork cambium; *c.c'*, ditto of lenticel; *co*, cortex. H, Part of transverse section of lateral root of *Buttercup; ep*, epidermis; *b.sh*, bundle-sheath, within which is pericambium; xylem seen as a dark cross; *l.r*, lateral root coming off from pericambium opposite a xylem mass; *r.h*, root hairs; *g.t*, ground tissue. K, Part of transverse section of *Lime* twig, four years old. *c*, Cork; *x*, 1, 2, 3, 4, annual rings of xylem; *ph*, phloem; *p*, pith; *co*, cortex.

loose rounded cells, and thus allows air to enter (Fig. 27, I). These are usually closed up in winter. The formation of *bark* that takes place in many trees, is caused by a *succession* of cork-cambium layers being developed in the cortex. The presence of a continuous covering is thus rendered compatible with growth in thickness. Suppose, for example, the stem represented in Fig. 27, I, continues to develop. The periderm will become too tight, and by its rupture the internal tissues would be exposed, were not some provision made. This provision consists in the development of a *new* cork-cambium within the old (*c.c*), which forms a new and larger corky coating, the periderm being flaked off. Thus the formation of bark commences.

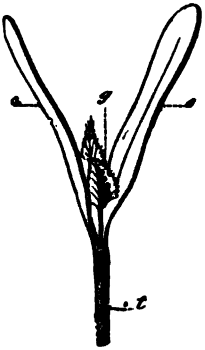

Fig. 28.—Part of young Dicotyledonous Plant showing c.c, cotyledons; *g*, succeeding leaves.

Sclerenchyma may occur in the ground-tissue, but not to the same extent as in Ferns. It forms a kind of sheath to the bundles of Monocotyledons. A *bundle-sheath* is present in Dicotyledons, as in Ferns and Pinus.

A modification of ground-tissue, known as *collenchyma*, is found in some stems (and leaf-stalks) beneath the epidermis. The walls of the cells are here thickened at their *angles* only, and the thickened parts are capable of swelling up considerably.

Various substances may be found within the ground-tissue, of which the most important are reserve materials, latex, and resin.

(1.) The *reserve-materials* stored up in winter wherewith to recommence growth in the following spring, are mainly in the form of *starch*. This is often, but not necessarily, stored up in *thickened* parts of the stem, as, *e.g.*, in the tubers of the Potato.

(2.) *Latex* or *milk* (contained in *laticiferous tissue*) is a solution of proteid matters, carbohydrates, &c., the characteristic appearance of which is due to the presence of minute particles of fat and waste products, such as resin and india-rubber in a state of suspension, *i.e.*, as an emulsion. In two of the most typical cases, the India-rubber plant (*Ficus elastica*) and the Spurges (*Euphorbia*), the milk is contained in delicate, much elongated *milk-cells* or *tubes*. In the latter, peculiar elongated starch-grains are present.

(3.) As in Pinus, *resin*, a waste product, accumulates in intercellular spaces, *resin-passages*, lined by small secretory-cells (*compare p.* 69). Such passages are found, for example, in the Ivy.

Air-containing intercellular spaces are contained in the ground-tissue of aquatic stems, external to the vascular cylinder.

(2.) **The Leaf.**—*External Characters.*—The earliest leaves of a plant are the *seed-leaves* or *cotyledons* (Fig. 28, C). These are much simpler in form than the succeeding leaves, and probably reproduce an ancestral character. Monocotyledons possess *one*, Dicotyledons *two*, hence the names.

Apart from the cotyledons, leaves may be placed under four headings:—

(*a.*) *Scale-leaves.*—These are usually simple brownish expansions, destitute of stalks, and attached to underground stems. They may also occur upon aerial stems, where their commonest function is to cover and protect the buds of trees (Fig. 29). In the Onion, thickened scale-leaves aggregated round a flat, disc-like stalk form a *bulb*, in which reserve-material is stored.

(*b.*) *Foliage-leaves*, including those structures ordinarily known as leaves. (*c.*) *Bracts.* (*d.*) *Flower-leaves.*

The last two kinds will be described under Reproductive Organs (*p.* 93).

The following remarks apply to the foliage-leaves:—

(*a.*) **Arrangement of Leaves.**—Leaves are folded in various ways while in the bud; and as this **prefoliation** or **vernation** is constant for the same species, it is of some systematic importance. Various terms are given—some, such as *imbricate* and *valvate*, referring to the relation of the leaves to one another (*e.g.*, the above terms mean respectively "overlapping" and "touching at the edges"), others referring to individual leaves, as *conduplicate*, folded once on the midrib, and *plicate*, folded several times.

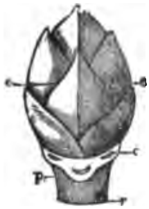

Fig. 29.—Leaf-bud of Sycamore showing *e. e*, scale leaves.

Phyllotaxis is the term applied to arrangement on the stem. When this is very short, the arrangement is difficult to make out, and the leaves are crowded into a tuft or rosette. Such leaves, and also those arising from underground stems, or the base of ordinary stems, are called *radical*, because they arise near the root. In contradistinction to this, other leaves are called *cauline*.

If more than one leaf is found at the same node (Fig. 48), a *whorl* is formed (*compare Chara*). If two leaves only make up the whorl, they are said to be *opposite*. If successive pairs are placed at right angles, so that four rows can be distinguished, the arrangement is *decussate*.

Leaves which grow out singly from the nodes are *scattered*. In this case, for any species, the angular distance between two successive leaves is constant. This expressed as a fraction of the circumference is known as the *divergence*. The commonest divergences are $\frac{1}{2}$ (all Grasses), $\frac{1}{3}$ (Alder), $\frac{2}{5}$ (Willow). The last occurs most frequently of the three, and may serve to illustrate the principle (Fig. 30). The "two-fifths" means that if the stem were telescoped so as to bring two successive leaves on the same level, they would be two-fifths of the stem's circumference apart. A spiral line, the *genetic spiral*, can be drawn round the stem, cutting all the insertions of the leaves. Starting from any leaf and proceeding upwards, the spiral will, after a certain number of turns, reach a leaf immediately over the first. In fact the leaves are arranged in vertical ranks called *orthostichies*. The fraction $\frac{2}{5}$ conveys the information that five of these are present, and also that the spiral must run *twice* round the stem from a particular leaf before it reaches the next leaf in the same orthostichy.

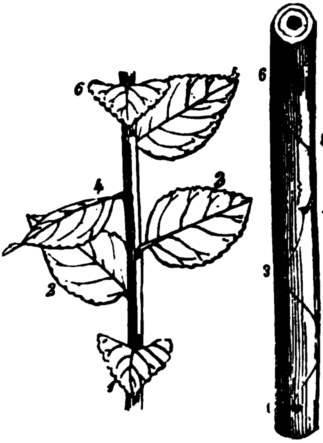

Fig. 30.—PHYLLOTAXIS (TWO-FIFTHS) OF CHERRY.—*a*. Part of branch; *b*. Diagram of same showing leaf attachments and genetic spiral.

From Mosses upwards, the spiral arrangement of leaves as described above can be distinguished. It was, however, thought advisable to introduce an account of it here for the first time.

Leaves are less permanent than stems. In this climate most plants possess *deciduous* leaves, which all fall off in the autumn. *Evergreens* lose their leaves gradually, and fresh ones are developed in the same way. Leaves which persist for long often have a horny texture. Soft leaves are termed *herbaceous*.

(*b*.) **Form of the Leaf.**—The great majority of leaves are more or less flattened, and expanded horizontally. They are also *bilaterally symmetrical—i.e.*, divisible into right and left halves, which are exact counterparts. If such a leaf is extended horizontally, the bisection will be effected by the *median* (antero-posterior) *plane*, a vertical plane passing through the centre of the stem and cutting the insertion of the leaf. Leaves may, however, be *unsymmetrical*, as in the Elm (Fig. 31), where the right and left halves are not exact counterparts. The horizontal position is not always assumed, and the plane of the leaf may cut the median plane obliquely, instead of at right angles, or even coincide with it (*Iris*). Typical leaves are also *bifacial*, the upper and under surfaces presenting marked structural differences.

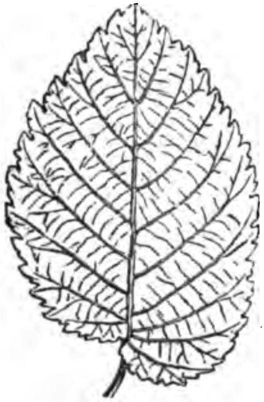

Fig. 31.—Leaf of Elm.

When most differentiated, a leaf exhibits three parts, the sheath, petiole, and lamina. (*a.*) The *sheath*, placed at the base of the leaf, is most conspicuously present in Grasses (Fig. 32, *gv*), and, as the name indicates, more or less enwraps the stem. (*b.*) The *petiole* is the leaf-stalk; and (*c.*) the *lamina*, the flattened blade. These are all three present at the same time in comparatively few leaves. The petiole is absent in Grasses, and the sheath in a large number of leaves, while many possess the lamina alone, and are then termed *sessile*. Special structures are sometimes developed, known as *stipules*, which are considered to belong to the sheath, and often appear to stand in place of it. They are then either leaf-like expansions placed at the junction with the stem, as in the Willow (Fig. 33), or temporary scale-like structures similarly situated, as in the Beech. In the Rose a small sheath is present from which two little pointed stipules grow out. These are termed *adnate* stipules.

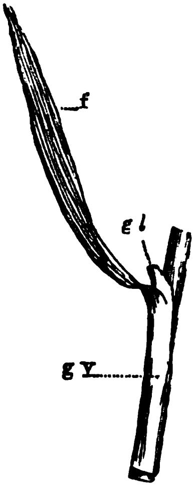

Fig. 32.—Leaf of a Grass.—*gv*, Sheath, *f*, lamina; *gl*, ligule.

In Grasses, a membranous *ligule* (Fig. 32, *gl*) grows out at the junction of lamina and sheath (*compare p.* 98).

The sessile condition involves some complications. Lobes of the leaf-base may then wrap round the stem, the leaf being *amplexicaul.* If the lobes actually fuse together, the leaf is *perfoliate* (Fig. 34), and the stem appears to pierce it. The stem may also be enclosed by the fusion of opposite leaves, which are then called *connate.* A leaf is *decurrent*, if wing-like prolongations grow from it down the sides of the stem.

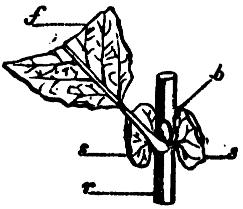

Fig. 33.—Part of Willow Leaf.—*r*, Stem; *b*, bud in axil; *f*, lamina, cut across; *s*,*s*, stipules.

The petiole is generally attached to the edge of the lamina, from which it may or may not be sharply marked off. It is *winged*, if the lamina is continued down its sides. Stipules are perhaps remains of such wings. The petiole may sometimes be attached to the under side of the leaf, which is then *peltate* (Fig. 35), as in Pennywort.

According to the *division* of the lamina, a leaf is either *simple*, or *compound*—*i.e.*, divided into smaller *leaflets*, which may again be subdivided. Upon this process the arrangement of vascular bundles has an important bearing. The leaves of Monocotyledons are usually simple, and commonly the principal veins run more or less *parallel* to their edges (Figs. 32 and 39).

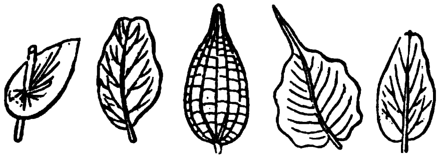

Fig. 34.—Perfoliate, Notched, Acuminate, Cuspidate, and Mucronate Leaves.

In Dicotyledons the venation may be *pinnate* (Fig. 36), primary veins coming off from a central midrib in a feather-like way, or it may be *palmate* (Fig. 39), several strong bundles entering from the petiole or the stem, and diverging in the lamina. In both cases the venation is *reticulate*, the veins ultimately breaking up into a close network.

The *edge* of a simple leaf may be *entire*, or more or less deeply *lobed*, the lobes corresponding to the principal veins. Successive degrees of lobation are indicated by the suffixes: *-fid*, *-partite*, and *-sect*. A leaf may thus be *pinnati-* or *palmati-fid*, &c. This division may be carried so far as to produce *leaflets*, and render the leaf *compound*. It may then be *pinnate* (Fig. 38), or *palmate* (Fig. 40), the leaflets either being arranged on the sides of a central axis or attached in a group to the petiole. Leaves are *bi-pinnate*, &c., when the leaflets again subdivide. A palmate leaf is

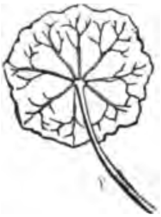

Fig. 35.

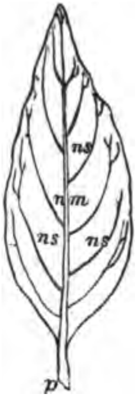

Fig. 36.

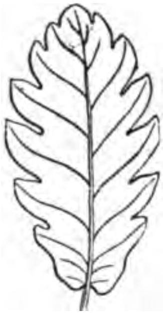

Fig. 37.

Fig. 35.—Peltate Leaf of Pennywort.
Fig. 36.—Leaf of Belladonna, entire and pinnately veined.—*p*, Petiole; *nm*, midrib; *ns*, primary veins.
Fig. 37.—Pinnatifid Leaf of Oak.
Fig. 38.—Pinnate Leaf of Robinia.

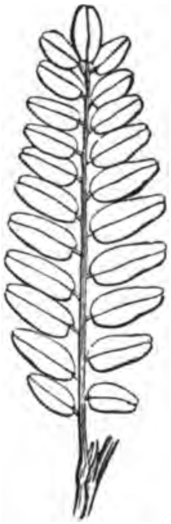

Fig. 38.

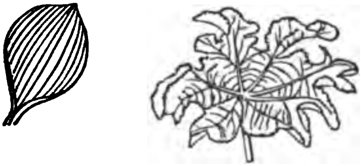

Fig. 39.—Parallel-veined and Palmatifid Leaves.

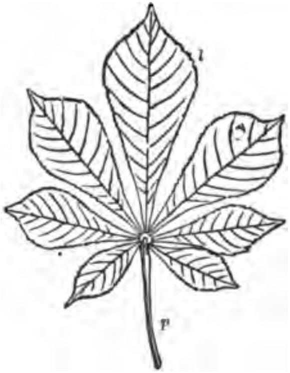

Fig. 40.—Palmate Leaf of Horse-Chestnut.

(Fig. 41) *ternate* if there are only three leaflets, *quadrifoliate* if there are four. Small indentations on the edge of a leaf

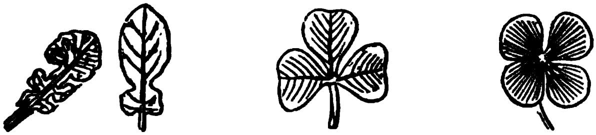

Fig. 41.—Lyrate, Fiddle-shaped, Ternate, and Quadrifoliate Leaves.

or leaflet are named according to their shape; if rounded, *crenate*, or *serrate*, if like the teeth of a saw, and so on. The *apex* also affords characters. It may be *acute* or *obtuse;* in the former case (Fig. 34) tapering gently, *acuminate*, or more suddenly, *cuspidate*, or with a hardened end, *mucronate*. The apex may also be *notched* (Fig. 34), *truncate* (Fig. 43), ending abruptly, &c.

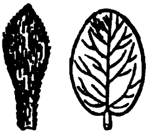

Fig. 42.—Spathulate and Oval Leaves.

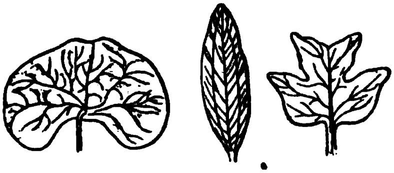

Fig. 43.—Reniform, Elliptical, and Truncate Leaves.

Outline of Leaves.—A very large number of descriptive terms is given to define the general shape of leaves, leaflets, &c. Only a few can be mentioned here. From a nearly circular,

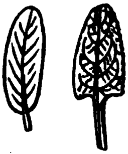

Fig. 44.—Oblong and Lobed Leaves.

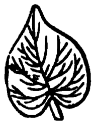

Fig. 45.—Cordate Leaf.

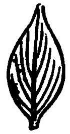

Fig. 46.—Ovate Leaf.

orbicular (Fig. 35) form, all gradations can be traced through *sub-orbicular* (Fig. 47), *oval* (Fig. 42), *elliptical* (Fig. 43), and *oblong*

(Fig. 44) to *linear*, like a grass (Figs. 32 and 48). The blade may be widest at the base, as *lobed* (Fig. 44), *cordate* (Fig. 45), heart-shaped; *ovate* (Fig 46), egg-shaped, and gradually tapering to a point; *sagittate* (Fig. 47), arrow-shaped; *lanceolate* (Fig. 48), long and gradually tapering, &c. Or, again, the blade may be widest at the apex, as in *ob-ovate*, *ob-cordate*, and *ob-lanceolate*, where the *ob-* reverses the meaning, and *lyrate* and *fiddle-shaped* (Fig. 41), which need no explanation.

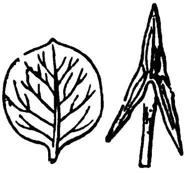

Fig. 47.—Sub-orbicular and Sagittate Leaves.

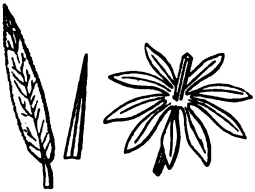

Fig. 48.—Lanceolate, Linear, and Whorled Leaves.

The leaf, like the stem, may depart very widely from its typical characters. It may be *cylindrical*, as in the Stonecrop, or *tubular*, as in the Onion. *Tendrils* may be formed by metamorphosis of parts of the leaf, in the Vetch—*e.g.*, from leaflets. Leaves may also be converted into *protective organs*—*e.g.*, spines, as in the Cacti (where the stems perform the leaf-functions), Barberry, and Gorse (*Ulex*). In the last case, Lubbock has drawn attention to the fact that, in the seedling-plant, the cotyledons are followed by ternate leaves which gradually pass into spines. This proves that the spines are modified leaves, and also that they have been acquired to suit special conditions, those first formed in the seedling indicating ancestral characters.

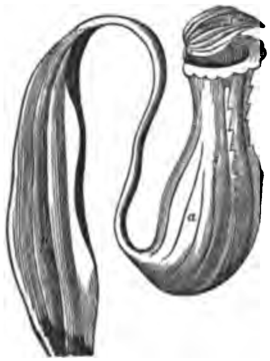

Fig. 49.—Pitcher of a Pitcher-Plant.

In connection with *nutrition*, it may be noted that, in the Pitcher-plants, the pitchers are modified leaves (Fig. 49).

Anatomy.—The external walls of the **Epidermis** are thickened into a continuous *cuticle*, which can often, in herbaceous leaves, be stripped off as a delicate transparent membrane. The **vascular bundles** of the lamina are the "veins," while the amount of **ground-tissue** varies greatly in amount according to the thickness of the leaf.

Histology.—The petiole essentially resembles a young stem, but it exhibits bilateral symmetry, which even extends to the vascular bundles, the xylem being placed uppermost. The lamina (Fig. 27, G), when *bifacial*, presents upper and lower layers of epidermis (*ep* and *ep'*), composed of flattened cells, usually with wavy outlines, which possess an external cuticle, thickest in leaves of firm texture, like those of the Holly. Very numerous **stomata** (*st*) are found in the lower epidermis, but these are much less frequent in, or absent from, the upper epidermis. Each *stoma* is bounded by two kidney-shaped *guard-cells* (Fig. 27, F, *g.c*). These contain chlorophyll-granules, which are, as a rule, absent from the other epidermal cells.

Chlorophyll-granules are found in the epidermis of many herbaceous leaves found in shady places. They also abound in the epidermis of submerged water-plants, which, however, is devoid of stomata.

Stomata are not confined to leaves, but may occur on any part of a plant except the root.

In a few cases—*e.g.*, the India-rubber-plant—the epidermis is more than one cell thick. Here also (and in a small number of other forms) peculiar bodies known as *cystoliths* are found within the epidermal cells. They consist of ingrowths from the cell-walls, impregnated and incrusted with carbonate of lime.

The mesophyll mainly consists of chlorophyll-containing parenchyma, the upper part of which is (in Dicotyledons) one or more cells thick, and termed the *palisade* (*p.p*) layer, because its cells are elongated and closely packed together at right angles to the epidermis, presenting a distant resemblance to palings. The lower or spongy parenchyma (*sp*) resembles that of the Fern (*p.* 56), and contains numerous air-spaces with which the stomata communicate. The vascular bundles present no very remarkable features. The Xylem is placed above the Phloem, there is no cambium, and a kind of sheath is formed by colourless parenchyma. In Grasses longitudinal bands of sclerenchyma connect the bundles with either epidermis.

Water-stomata are found in some plants, from which water, with various substances in solution, evaporates. These are situated over the ends of small masses of specially modified parenchymatous cells (glandular-cells), in which vascular bundles terminate, and which are known as *water-glands.*

In cylindrical leaves, like those of the Stonecrop, which are not bifacial, a *centric* type of structure is found, the tissues being arranged symmetrically, and the mesophyll without a palisade layer.

(3.) **The Root.**—In Dicotyledons the radicle of the embryo elongates and produces the *primary root,* which is termed a *tap-root.* This may sometimes be much thickened, so as to serve as a reservoir of reserve-material, as in the Dahlia and Beet-root. All other roots are developed laterally, either as *secondary roots* from the primary, or as *adventitious roots* from the stem. In Monocotyledons the radicle does not elongate, and the roots are *fibrous—i.e.,* consisting of a mass of secondary and adventitious roots growing out from the short primary root and stem. This is comparable to the shortening previously mentioned as occurring in the stem. Adventitious roots may be used for climbing purposes, as in the Ivy.

Modifications of the root occur in *epiphytes* and *parasites.* In the former group plants are included which simply live upon other plants (whereas parasites prey upon them), as, *e.g.,* many tropical Orchids. These possess *aerial* roots which subserve attachment, and are also modified for the absorption of nutriment (other than carbon dioxide) from the surrounding air (in the form of aqueous vapour and dust). Parasites, on the other hand, possess *sucker-roots,* which penetrate the tissues of the host and absorb nutriment from them.

Anatomy and Histology.—(*a.*) **Growing Point.**—This presents dermatogen, periblem, and plerome. The root-cap may have a special layer of initial cells for itself, the *calyptrogen,* or it may be formed by division of the dermatogen (Fig. 50). For the anatomy of the permanent tissue *compare* Pinus, *p.* 72, with which Dicotyledons generally agree. The roots of Monocotyledons do not exhibit secondary thickening, and there are usually a large number of alternating masses of xylem and phloem in the vascular cylinder.

(4.) **The Trichome.**—The presence of hairs of various kinds upon leaves and stems gives rise to characteristic appearances,

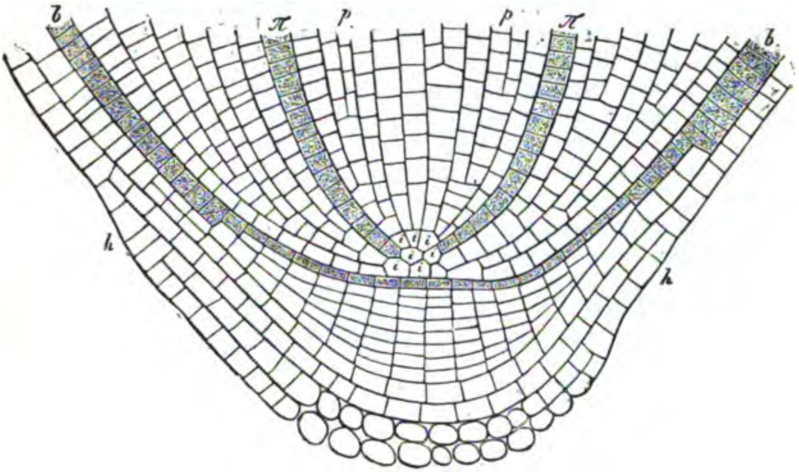

Fig. 50.—Longitudinal Section through Apex of Young Sunflower Root (from *Sachs* after *Reinke*).—*hh*, Root-cap; *bb*, dermatogen, from which this as well as epidermis originates. From π to π, plerome; between π and *b*, periblem; *i*, *i*, *i*, initial-cells.

and many systematic terms are used to express these, as *pubescent*, with soft hairs; *hirsute*, very hairy; *silky*, with soft shining hairs, &c. The term *glabrous* denotes absence of hairs.

Histology.—The *root-hairs* (Fig. 27, H, *r.h*), abundantly present on roots, are unicellular and unbranched. Many hairs are thread-like or conical, and may be branched in various ways, Most are multicellular. *Glandular* hairs occur in many plants. and these generally consist of a stalk made up of one or more cells, upon which is placed a rounded cell or group of cells, secreting resin or ethereal oil. Such structures are common, *e.g.*, on the leaves of Lavender, and are there overarched and protected by branched hairs.

Trichomes may also occur in the form of scales.

2. Reproductive Organs.—*External Characters.*—As in Pinus *flowers*, *i.e.*, "axes bearing sporophylls," are present, but are here much more highly specialized. The word "flower" was in fact first applied to these structures as found in Angiosperms, their conspicuous appearance naturally attracting attention. The discovery of their essential characters, however, as embodied in the definition, rendered it necessary to extend the term beyond its original signification.

(*a.*) **Arrangement of Flowers.**—Sometimes flowers terminate the main axis, or appear singly in the leaf-axils. This, however, is a comparatively rare arrangement. Far more commonly special systems of branches are present, which bear numerous flowers. These systems are *inflorescences.* Foliage-leaves are not found upon them, but their branches usually spring from the axils of small and simple leaves known as *bracts.*

The principal kinds of inflorescence are classified as follows:—

I. RACEMOSE.—The main axis (*rachis*), which may or may not end in a flower, produces lateral branches that do not usually overtop it.

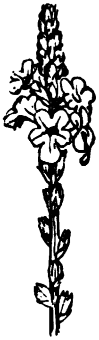

Fig. 51.—SPIKE OF VERBENA.

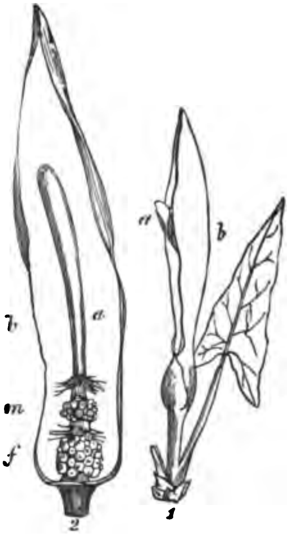

Fig. 52.—SPADIX OF ARUM.—1, Shows spadix, *a*, almost enveloped by spathe, *b*; 2, spathe, *b*, opened to display spadix, *a*; *f*, female flowers; *m*, male flowers.

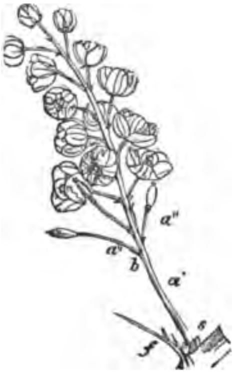

Fig. 53.—RACEME OF BARBERRY.

Rachis long.

1. **Spike.**—Rachis slender, bearing *sessile* flowers. *Ex.* Verbena (Fig. 51).
2. **Spadix.**—Like a spike, but with a thickened rachis. Enclosed in a large bract, the *spathe.* *Ex.* Arum (Fig. 52).
3. **Raceme.**—Axis with stalked flowers. *Ex.* Barberry (Fig. 53).

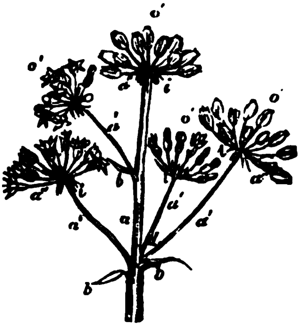

Fig. 54.—UMBELS OF ARALIA.

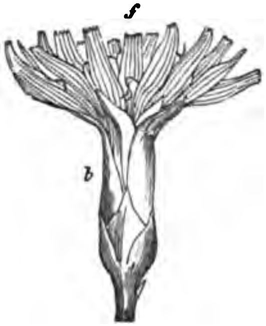

Fig. 55.—CAPITULUM OF SCORZONERA.—*b*, Bracts; *f*, florets.

Rachis short.

4. **Umbel.**—A number of branches spring from the shortened rachis at the same level. These are of about equal length, and terminate in flowers. *Ex.* Ivy, Aralia (Fig. 54).
5. **Capitulum** (Head).—The end of the rachis is flattened out and bears a group of sessile flowers, the whole surrounded by a collection of bracts constituting an *involucre.* *Ex.* Daisy, Scorzonera (Fig. 55).

In the last two cases the internodes of the rachis are suppressed. An umbel is, so to speak, a telescoped raceme, and a capitulum a telescoped spike.

Compound racemose inflorescences are formed if the lateral axes originate others instead of ending in flowers. Thus in a *compound spike* (*ex.* Wheat), the lateral axes are spikes, in a *compound raceme* or *panicle* (*ex.* Grapevine), they are racemes, and in a *compound umbel* (*ex.* Parsley) they are umbels.

II. CYMOSE.—The main axis ends in a flower, just below which branches come off that overtop it. These branch on the same principle.

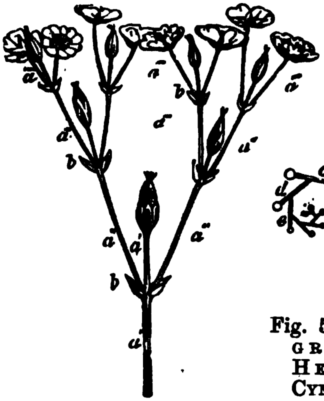

Fig. 56.—Cyme of Mouse-ear Chickweed (Cerastium).

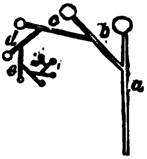

Fig. 57.—Diagram of Helicoid Cyme.

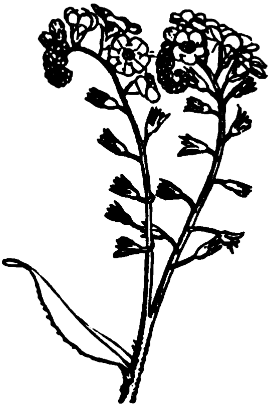

Fig. 58.—Helicoid Cyme of Forget-me-not.

1. **Cyme** proper.—The main axis can be distinguished as such (Fig. 56).
2. **Sympodial Cymes.**—The apparent main axis is partly formed by lateral axes.
   - (*a.*) *Scorpioid Cyme.*—Alternate right and left branches form the apparent main axis.
   - (*b.*) *Helicoid Cyme.*—The apparent main axis is spiral, and formed by a series of right or left branches. *Ex.* Forget-me-not (Figs. 57 and 58).

The branching of vegetative organs may be either racemose or cymose.

(*b.*) **Parts of the Flower.**—Before describing these it may be well to mention that the term *peduncle* is applied to the flower-stalk. Upon this small *bracteoles* may be placed.

The flowers are usually *bisexual*, but they may be *unisexual.*

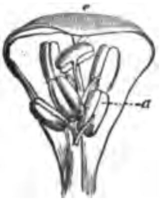

Fig. 59.—Male Flower of Hazel, separated from Catkin.—*e*, Bract; *a*, stamens.

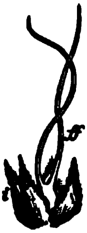

Fig. 60.—Female Flower of Hazel, separated from cluster.—*i*, Bract; *ff*, flower.

In the latter case the plant is either *monœcious,* as the Hazel (Figs. 59 and 60), or *diœcious,* as the Willow.

In *polygamous* forms—*e.g.*, the Ash, both unisexual and bisexual flowers are found on the same plant.

A typical bisexual flower contains several kinds of *flower-leaves,* crowded together upon the end of the peduncle, which, by suppression of internodes, forms a swollen, flattened, or cup-like structure, the *torus* or *floral receptacle.* Upon this the flower-leaves may be either *spirally* arranged, as in the white Water-lily (Fig. 61), when their number is usually large but inconstant, or they may be *whorled,* when their number is small and constant. The contrasted terms *spiral* and *cyclic* may be used to express this fact, but all the intermediate gradations occur.

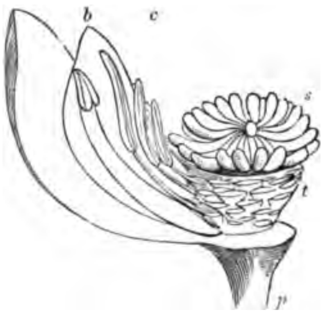

Fig. 61.—FLOWER OF WHITE WATER LILY, most of floral leaves removed.—*p*, Peduncle; *t*, torus, upon which are seen numerous spirally-arranged scars where floral leaves have been attached; *a*, sepal; *b*, petal; *c*, stamens; *s*, carpels.

The flower-leaves are divided into *perianth leaves* and *sporophylls,* to which these form an investment.

(1.) **Perianth.**—The term *Prefloration* or Æstivation is applied to the way in which these leaves are folded in the bud.

The perianth may be entirely wanting, as in the Arum, or it may be very inconspicuous, especially in trees and grasses. It is generally composed, however, of two whorls, an outer *calyx,* made up of *sepals,* and an inner *corolla,* the constituents of which are *petals.* These usually alternate with one another. The perianth leaves (and sporophylls) of Monocotyledons are very generally arranged in threes (Fig. 72), those of Dicotyledons in fours or fives (Figs. 64 and 66). Multiples of these numbers also occur very frequently.

(*a.*) *Calyx.*—This is generally green, but, more particularly in Monocotyledons—*e.g.*, the Tulip—other and brighter colours may be assumed. The sepals are then termed *petaloid,* because such tints are distinctive of petals. The *sepals* may be distinct from one another, *chorisepalous* (Fig. 62), in which case they resemble simple foliage-leaves in shape, and are usually broadest at the base. On the other hand, the calyx may be a tube, variously shaped, in which teeth indicate the number of sepals. This is the *gamosepalous* condition (Fig. 65).

A calyx in which all the sepals are alike is *regular*, otherwise it is *irregular*.

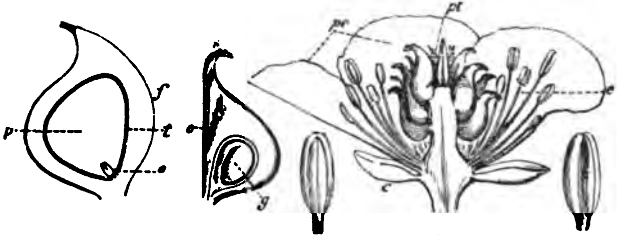

Fig. 62.—VERTICAL SECTION, &c., OF BUTTERCUP FLOWER.—*c*, Calyx; *pe*, corolla; *e*, andræcium; *pi*, gynœcium. Below the section are front and back views of anther. To left of this a carpel opened; *s*, stigma; *o*, ovary; *g*, ovule. To extreme left section of a carpel; *t*, coats of ovule; *p*, endosperm; *e*, embryo.

(*b.*) *Corolla.*—This is in typical cases brightly coloured. If green, the petals are termed *sepaloid*. The term *choripetalous* is used when the petals are distinct (Fig. 62). They are then of more complicated shape than sepals (Fig. 63), and generally possess a narrow stalk (claw) and expanded lamina (limb). Upon the upper side a small outgrowth, the *ligule*, may be given off at the junction of the two. The ligules collectively form the *corona*, conspicuous in Narcissus. The corolla is *gamopetalous*, if more or less tubular.

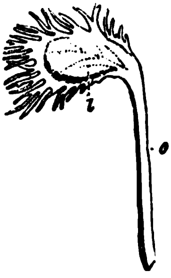

Fig. 63.—PETAL OF PINK.—*o*, Claw; *l*, limb.

Both choripetalous and gamopetalous corollæ may be *regular* (Fig. 64) or *irregular* (Figs. 65 and 66), like the calyx. The irregularity may be very slight or much exaggerated, and many different terms are used to describe these various conditions. Two of the most striking forms are the *labiate* (Fig. 65), or lipped, like the Dead Nettle, Toadflax, and Orchid, and the *papilionaceous* (Fig. 66). In the latter case, the form is somewhat butterfly-shaped, and five petals are present—a large upright *standard* (*e*), two lateral *wings* (*a*), and between them a *keel* (*b*), enclosing the sporophylls, and formed by two imperfectly united petals. Examples are found in the Sweet-pea, Gorse, Bird's-foot-Trefoil, &c.

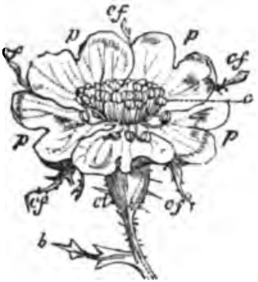

Fig 64.

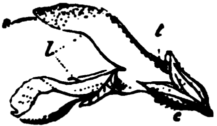

Fig. 65.

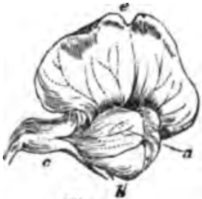

Fig. 66.

Fig. 64.—FLOWER OF ROSE.—*b*, Bract; *ct*, torus; *cf*, *cf*, sepals; *p*, *p*, petals; *e*, stamens.

Fig. 65.—LABIATE COROLLA OF SALVIA.—*c*, Calyx; *l*, Lips; *s*, Stigma.

Fig. 66.—PAPILIONACEOUS FLOWER OF SWEET PEA.—*c*, Calyx; *e*, standard; *a*, wing; *b*, keel.

(2.) **Sporophylls.**—These are of two kinds, male (stamens) and female (carpels), which occur together in bisexual flowers. In many unisexual flowers, rudiments of the other kind of sporophyll may be detected. The stamens are collectively termed the andrœcium, and the carpels the gynœcium.

(*a.*) *Andrœcium.*—This may consist of one or more stamens. Each of these is typically made up of a stalk, the *filament*, and a dilated end, the *anther*, usually consisting of two lobes. Between these the filament extends as the *connective*, and may be continued beyond them. The stamens are sometimes united in the filament region into one or more groups. In the Gorse one group is present. This is the *monadelphous* condition. The terms *di-* and *poly-adelphous* are applied to two or more groups, as in the Sweet-Pea and Hypericum (Fig. 67). The filament is typically slender, but may be more or less thickened, broadened, or produced into processes.

If the filament and connective are in the same line, the anther is *basifixed*, but if the filament is attached at the back of the anther, it is *dorsifixed*. In the latter case the union may be constricted, so that the anther swings freely or is *versatile* as in Grasses (Fig. 68). The connective may be broadened out, sometimes in such a way that the anther-lobes are not parallel, or are widely separated.

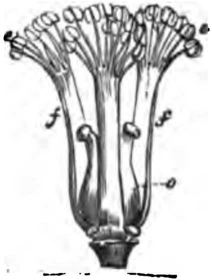

Fig. 67.—POLYADELPHOUS STAMENS OF HYPERICUM.

In the latter case one lobe may be aborted, as in *Salvia* (Fig. 69). The anther-lobes may be provided with appendages. In each of them two *pollen-sacs* (microsporangia) are usually imbedded. These contain *pollen,* which may be dehisced through slits or pores. The former may be on the inside or outside, according to the position of the anther-lobes, when the dehiscence is *introrse* or *extrorse.* The pollen-grains (microspores) generally appear to the eye as a yellowish dust, but sometimes the grains in each pollen-sac may adhere together into a *pollinium* (Fig. 70 and *p.* 110). The stamens may be united together by their anthers, and are then, as in the Daisy, Dandelion, &c., *syngenesious.*

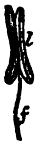

Fig. 68.

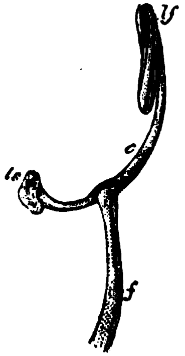

Fig. 69.

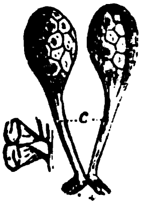

Fig. 70.

Fig. 68.—Versatile Anther of Grass.—*f*, Filament; *l*, anther.
Fig. 69.—Stamen of Salvia.—*f*, Filament; *c*, connective; *lf*, fertile anther lobe; *ls*, aborted anther lobe.
Fig. 70.—Pollinia of Orchis.

Stamens are sometimes of unequal length, the commonest conditions of this sort are the *tetradynamous,* four long and two short, *e.g.*, Wall-flower, and *didynamous,* two long and two short, *e.g.*, Dead-nettle.

(*b.*) *Gynœcium.*—There may be only one carpel, as in the Gorse, or more than one, when they remain distinct, *apocarpous* (Fig. 62), or are fused together, *syncarpous.* It will be the simplest plan to commence with a Gynœcium like that of the Gorse (Fig. 71, D). The single carpel here present is a leaf which has been folded up so that its lower part, or *ovary*, forms a chamber in which the ovules (macrosporangia) are contained. The arrangement of the ovules is termed *placentation*. In this case the edges of the carpel have been thickened to form a projecting *placenta* (*p*) running down one side of the ovary—*i.e.*, that side where the edges of the leaf have fused together (ventral suture, *v.s*). This is *marginal* placentation. The upper part of the carpel forms a slender *style*, which terminates in a viscid patch, the *stigma*. This type of carpel, more or less modified, is found where the carpels remain separate. The variations that occur are mainly in shape. The stigma, by absence of the style, may be *sessile*.

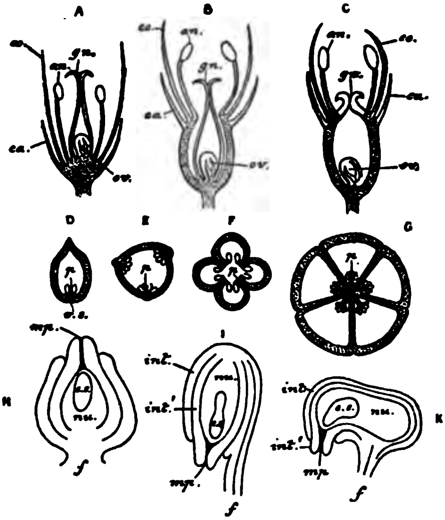

Fig. 71.—Diagrams of Relations of Flower Leaves (after *Prantl*).—A, B, C, Hypogynous, perigynous, and epigynous flowers in longitudinal section. The torus is dotted. *ca*, Calyx; *co*, corolla; *an*, andrœcium; *gn*, gynœcium; *ov*, ovule. D-G, Ovaries in transverse section. D, A simple ovary. E, Parietal placentation. F, Syncarpous ovary partly subdivided. G, Syncarpous ovary subdivided into chambers; *p*, placenta; *v.s.*, ventral suture. H, I, K, Straight, inverted, and bent ovules in longitudinal section; *f*, funicle; *mp*, micropyle; *int* and *int'*, integuments; *nu*, nucellus; *e.s*, embryo sac.

In the *syncarpous* gynœcium two or more carpels are present, which have partly or completely fused. A compound ovary thus arises (Fig. 71, E, F, G), one- or many-chambered, or in an intermediate condition. A one-chambered ovary may be formed by carpels, which mutually adhere at their edges, as in the Violet. The placentation is then *parietal* (E), the placentas being found in the side walls. In other cases the carpels are more or less folded before fusion. If completely so, as in the Tulip, the placentation is *axile* (G), and formed by the aggregation of marginal placentas at the centre.

All the preceding remarks apply to *superior* ovaries (*compare p.* 103).

The styles and stigmas in a syncarpous gynœcium may be distinct or more or less fused.

The *ovules* vary much in number. Their stalks, when present, are called *funicles.*

Nectaries.—These are parts of the flower which secrete a sugary fluid, *nectar*, by which insects are attracted. They do not come under any special morphological category, as they may be formed in various parts of the flower. They may be simple glandular spots, or protuberances, and the nectar may either accumulate near the origins of the floral leaves, or in special receptacles. In the Buttercup, a small pit-like nectary, covered by a scale, is found on each petal, near its base. Very commonly nectaries are found on the torus as small projections between the bases of the filaments, as in the Wallflower. Receptacles are usually formed as hollow *spurs* belonging to the sepals or petals. The walls of these may themselves secrete nectar, or glandular processes may project into them, as in the Violet or Pansy, where nectar-secreting outgrowths from two of the stamens project into a spurred petal.

Anatomy and Histology.—(1.) *Development and Structure of the Pollen-sacs* (*microsporangia*).—The cells beneath the epidermis of each lobe of the embryo-anther become differentiated in the region of the future pollen-sac into *archesporium*, outside of which is a layer of cells, the *primary tapetum.* The archesporium is made up of cells, which divide a little and then become the *pollen-mother-cells.* Each of these again divides to produce four pollen-grains (microspores).

The *primary tapetum* typically divides into three layers—(*a.*) *tapetum proper*, most internal, the cells of which become disorganized; (*b.*) a *middle* delicate layer; and (*c.*) an external *fibrous layer*, to which last the dehiscence is due. The fibrous layer is absent in anthers which do not dehisce.

The pollen-grains are invested by a delicate cellulose membrane, the *intine*, external to which is a cuticularized *extine*, often raised into knobs, spines, ridges, &c.

(2.) *Development and Structure of the Ovules.*—These arise as outgrowths of the placenta, formed by groups of cells partly epidermal, and partly belonging to the deeper tissue. As in Pinus (*p.* 74), the mature ovule (Fig. 71, K, I, H) consists of a central *nucellus* (*nu*), but this often possesses two integuments (*int.*), especially in Monocotyledons. There is usually a stalk, or *funicle* (*f*). If the ovule is in the same line as the funicle, it is *straight* (H), if sharply curved upon it, *inverted* (I), if curved upon itself, *bent* (K).

(*c.*) **Relative position of Parts of the Flower.**—The form of the torus has an important bearing upon this. According to its characters the flower may be hypogynous, perigynous, or epigynous (Fig. 71). (*a.*) In the *hypogynous* flower (A) the torus is conical or flattened, and the origin of the gynœcium is raised above or, at any rate, is on the same level as the origin of the andrœcium. (*b.*) The torus of a *perigynous* flower (B) is hollowed out into a cup, upon the edges of which the perianth and andrœcium are inserted. The gynœcium springs from the bottom of the cup. In these two cases the ovary is *superior*. Finally (*c.*) in an *epigynous* flower (C), the torus is not only hollow, but actually assists in forming the wall of the *inferior* ovary, which is merely roofed in by the gynœcium. The carpels may, however, be produced downwards into the inferior ovary to form placentas (*Orchis*) or chambers (*Iris*). As might be expected, numerous gradations occur between these three conditions. Good examples of hypogynous, perigynous, and epigynous flowers are found in the Buttercup, Rose, and Parsnip respectively.

The stamens are *epipetalous* if situated on the corolla, as in the Primrose, *gynandrous* if on the gynœcium, as in the Orchis. The side of a flower turned towards the axis on which it is situated is termed *posterior*, the *anterior* side being turned away. The remaining two sides are lateral. As in the case of the foliage-leaf (*p.* 86) a vertical *median* or *antero-posterior* plane can be distinguished (Fig. 72, *m. pl*), which divides the axis longitudinally and bisects the flower from back to front, dividing it into right and left halves. The flower is divided into anterior and posterior halves by a *lateral plane* (*tr. pl*), vertical and perpendicular to the preceding. Two other vertical planes, *oblique planes* (*ob. pl*), may also be mentioned, which cut the two other planes at 45°.

In most plants the flower-leaves are arranged in whorls (*compare p.* 97); but this may only apply to part of the flower, as in the Buttercup, where the perianth is whorled, while the sporophylls are spirally arranged. The relations of the different parts may be very well represented by a *floral diagram* (Fig. 72), which, for elementary purposes, is simply the ground-plan of a flower in which the different leaves are represented by conventional marks. The whorls are indicated by circles upon which sepals and petals are represented by lines with and without a midrib, the stamens by marks shaped like cross-sections of anthers, and the gynœcium like the cross-section of an ovary. The position of the axis is shown by a dot. Flowers are termed *eucyclic*, if the whorls all contain the same number of parts, and these alternate with one another. There are very commonly two whorls in the andrœcium. Deviations from the eucyclic type are very common, and depend either upon variations in number, or in position. The term *opposite* is used if the parts of a whorl correspond in position with the parts of the preceding or succeeding whorl, instead of alternating with them.

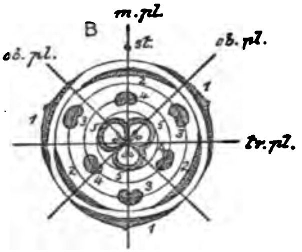

Fig. 72.—Floral Diagram of Lily.—*st*, Position of stem; *m.pl*, antero-posterior plane; *tr.pl.* lateral plane; *ob.pl*, oblique planes; 1, 1, 1, sepals; 2, 2, 2, petals; 3, 3, 3, outer stamens; 4, 4, 4, inner stamens; 5, 5, 5, carpels.

(*d.*) **Symmetry of Flowers.**—The flower is said to be *polysymmetrical* or *radially symmetrical*, if it can be divided into similar halves by more than one vertical plane. If, on the other hand, it can be so divided by only one plane, it is *monosymmetrical* or *bilaterally symmetrical.* In this case, the plane so dividing it is the median plane, and the halves are right and left.

Monosymmetrical flowers are also called *Zygomorphous* or *irregular.* The term *regular* is given to flowers in which both calyx and corolla are monosymmetrical.

The symmetry of the flower has an important bearing on pollination, for which *see p.* 109.

II. OOPHYTE.—As in Pinus, this may be treated under the two heads of male prothallus and female prothallus.

(*a.*) **Male Prothallus.**—The Pollen-grain (microspore) divides into two cells—a smaller vegetative cell, and a larger fertile cell, not separated by a cell-wall. The former may or may not divide to form two or three others. Upon the stigma, a *pollen-tube* grows out from the fertile cell, which breaks through the *extine.* This represents an antheridium, and its end contains, just before fertilization, a *generative nucleus,* which usually divides into two or more smaller nuclei, corresponding to *spermatozoids.*

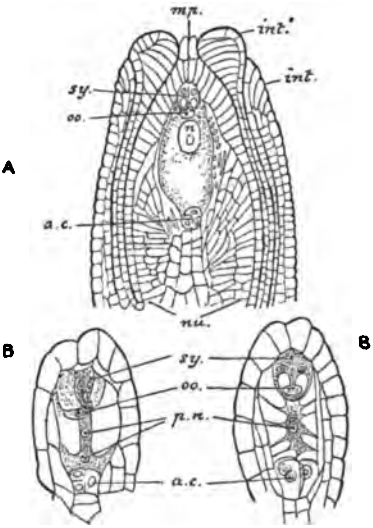

Fig. 73.—Embryo-sac of Angiosperm (after *Strasburger*).—A, *int, int'*, Integuments; *mp*, micropyle; *nu*, nucellus; *sy*, synergidæ; *oo*, oosphere; *a.c*, antipodal-cells; *n*, secondary nucleus of embryo-sac. B and B', formation of secondary nucleus of embryo-sac; the polar nuclei, *p.n*, are moving towards one another in B, and are fused in B'. Other letters as before.

(*b.*) **Female Prothallus** (Fig. 73).—This, as in Pinus, is the *embryo-sac,* which arises within the nucellus, as a larger cell than the rest. There is no considerable formation of endosperm within the embryo-sac, before fertilization, as in Pinus. In other words, the prothallus is very rudimentary. Certain cells are formed, however, before this epoch. The nucleus of the embryo-sac divides into two, and the halves travel to opposite ends, each of them again subdividing to produce four nuclei. One of these travels from either end, and the two, fusing in the centre, constitute the *secondary nucleus* of the embryo-sac. The two nuclei that fuse thus may be termed *polar nuclei* (*p.n*). The three nuclei at the micropylar end become surrounded with protoplasm to constitute a three-celled *egg-apparatus,* probably representing three rudimentary archegonia. Two of them, the *synergidæ* (*sy*), are placed at the surface, and the third, or *oosphere,* below these. The three nuclei at the other end of the embryo-sac become surrounded with protoplasm, and form the *antipodal-cells* (*ac*).

These probably correspond to the endosperm of Pinus, and may be regarded as representing the vegetative part of an extremely rudimentary female prothallus. The egg-apparatus is in that case the reproductive part of this prothallus.

PHYSIOLOGY.

1. **Nutrition** (*Compare p.* 24).—In the higher green plants, from the Fern upwards, the nutrition differs from that of simple forms, in that there is a physiological division of labour between the different organs. The epidermal-cells of the green parts of the plant (more especially of the leaves) absorb from the air carbon dioxide, which is decomposed in the chlorophyll-granules present in the mesophyll and less frequently in the epidermal cells themselves. This, as in other cases, only goes on under the influence of sunlight. It is to increase their efficiency for absorptive and other purposes (*see below*) that leaves are so much flattened and subdivided. In this climate, at any rate, leaves are arranged with reference to the stem and one another, so as to gain as much surface as possible. In water-plants the leaves are often very much divided, and by this means a maximum surface is secured for the absorption of the carbon dioxide sparingly dissolved in the surrounding water. It is also common for the leaves of herbaceous plants to be very much divided, and Grant Allen suggests that this is caused by "the fierce competition that goes on for the carbon of the air between the small matted undergrowth of every thicket and hedgerow."

On the other hand, *roots* are concerned in land-plants with the absorption of water and salts from the soil, the particles of which adhere very closely to them. The *root-hairs* are the main agents concerned in the process, and, in virtue of an acid sap often possessed, various matters insoluble in water are brought into a state of solution, and can thus diffuse into the plant.

The *sucker-roots* of parasites simply absorb the elaborated juices of the plants upon which they prey, and in such cases the necessity for chlorophyll is done away with, and that substance may be absent, the "colourless" condition (*see p.* 24) being assumed, as, *e.g.*, in the Dodder. The *air-roots* of epiphytes are specially modified so as to condense water upon their surface, the necessary salts being supplied by the dust present in the atmosphere.

Circulation.—Both water and gases travel through the tissues of plants in various directions, and their course is largely determined by the nature of the tissues, which are here highly differentiated.

(1.) *Movement of water*, with various substances in solution, may be effected by *osmosis* from cell to cell, as in non-vascular plants, where it is the only method. It may also be caused in other ways. Many plants, when cut through in the spring, "bleed," *i.e.*, sap flows from the cut surface. This is caused by *root-pressure;* very vigorous absorption taking place by the root, fluid is forced into the cavities of the vessels, and passes along them. Water may also travel along the lignified walls of the xylem elements, and, especially in the Fern, of the sclerenchyma. The cavities of these structures are, at the same time, occupied by gases. By this road the currents travel which compensate for *transpiration*, the name given to the evaporation that is constantly taking place from the surfaces of plants, more especially from the leaves—the evaporating liquid passing out by the stomata, which can by opening widely promote it.* Transpiration is of great importance, because it helps absorption and circulation. In the chlorophyll-granules, organic substances of nitrogenous and non-nitrogenous nature are produced. Starch is the most important substance in the latter category. These substances will serve either as *plastic material* to build up parts of the plant, or as *reserve material* to be stored up for future use. In either case they pass into solution, and travel by various roads to their destination. The solution is apparently effected by *unorganized ferments* (*compare Yeast*) present in the plant. The non-nitrogenous substances travel by the ground-tissue, while the nitrogenous travel in the same way or by *sieve-tubes* and *laticiferous tissue*. In the case of reserve materials, a re-conversion into the insoluble form takes place in the storing receptacle, tuber, rhizome, seed, or what not.

Insectivorous plants, as the Sun-dew and Pitcher-plants, catch insects by various contrivances, and the cells of the pitcher or other apparatus secrete a fluid which digests them—*i.e.*, brings them into a soluble diffusible state.

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* Guard-cells *always* contain chlorophyll-granules. Hence in the daytime they are actively assimilating. This causes them to become very turgid, the expression of which is found in greater curvature. The stomata are thus widely opened. The exact opposite occurs at night.

(2.) *Movement of Gases.*—This is rendered possible by the presence of intercellular spaces, and air-containing vessels and tracheides.

2. Destructive Metabolism.

(1.) **Respiration** (*compare p.* 13).—The leaves are, more especially, the organs of respiration, which also goes on very actively in germinating seeds, and is most energetic in expanded flowers. Not only carbon dioxide, but also watery vapour is given out in the process. A certain amount of free oxygen is necessary to the well-being of roots, and hence the reason for the lateral lines in the rhizome of the fern (*p.* 52), under which the sclerenchyma is absent.

(2.) **Nitrogenous Waste-products** are more frequently stored up in various parts of the plant than actually excreted. The latter is, however, the case in certain plants, such as the May (*Cratægus*), the odour of which is due to the evolution of volatile products of this nature. It may here be remarked that this class of waste-products is formed in plants by much more complicated substances than are the same products in animals, the most important being compound ammonias. Amongst these may be mentioned *alkaloids*, such as strychnine, nicotine, &c., which are often stored up in parts of the plant, seeds, bark, &c., that are thrown off. They are thus indirectly got rid of.

3. Reproduction.—*Sporophyte.*—This may reproduce vegetatively or asexually.

(*a.*) **Vegetative Reproduction** is effected in various ways as, *e.g.*, by buds developed upon tubers, bulbs, and corms. Many plants also propagate themselves by creeping stems of different kinds, such as the *runners* of the Strawberry.

(*b.*) **Asexual Reproduction** leads to the formation of microspores (pollen-grains) and macrospores (embryo-sacs). *See p.* 64.

Sexual Reproduction is exhibited by the *oophyte.* Cross-pollination is secured and self-pollination prevented in a variety of ways.

(1.) *Prevention of Self-pollination.*—The stamens and carpels may occur in different flowers or upon different plants. In bi-sexual flowers they are frequently mature at different times, the stamens in most cases ripening first, or the parts may be so arranged as to render self-pollination impossible.

(2.) *Securement of Cross-pollination.*—A number of agents are more or less concerned in *pollination*—that is, in conveying pollen from the stamens of one plant to the stigmas or receptive surfaces of others. These are wind, insects, water, birds, and snails.

(*a.*) *Wind-pollinated* (anemophilous) flowers are usually regular, green in colour, and destitute of scent and nectar. They mature early in the spring, so that the pollen, which is produced in great abundance, is not intercepted by foliage. The stigmas are, moreover, adapted to catch the pollen, by possessing hairs or by being branched. Most trees are examples of the group.

(*b.*) *Insect-pollinated* (entomophilous) flowers include the vast majority. They exhibit many peculiarities, the most important being irregularity and other structural features, as well as the possession of colour (other than green), odour, and nectar. The last three features serve to attract insects, the others cause them to effect the purpose in view. The *colours* may attract insects generally, or only special insects. Bees, for example, prefer blue, flies yellow or flesh-colour. White flowers are often pollinated by night-insects. The effect of colour is augmented in many cases by aggregation, as, for example, in the capitulum of the Daisy.

Odour may also prove attractive, either fragrant or fœtid, as the case may be.

The great inducement, however, for insects to visit plants is *nectar*, a sugary fluid secreted (as we have seen, *p.* 102) in various places. Lines, &c., on the petals may converge to the nectaries, and serve as "honey-guides." The principle of the structural peculiarities is, that the nectar shall be so situated that, in procuring it, the insects must at the same time effect pollination, and receive more pollen for other flowers. In the White Dead-Nettle the nectar is at the bottom of the flower, the lower lip forms a landing-stage, and the upper lip overhangs the stamens and stigma. The latter projects in such a way that the insect's back, which is often dusted with pollen from a flower previously visited, must touch it first. Pollination is thus effected, and the stamens, which are next touched, shed their pollen on to the insect. Some flowers, as the Gorse and Broom, are in a state of tension, which is disturbed by the insect, and results in the discharge of a shower of pollen upon it. The irregularity thus secures a suitable position of parts, and it is often correlated with the shapes of special insects. This is especially the case with bee-pollinated flowers.

The most remarkable cases are found among Orchids. Here there is usually a single stamen, fused with the top of the gynœcium. It contains two masses of pollen, agglutinated into *pollinia.* These are so arranged that an insect alighting on the lower lip to procure the nectar contained in the spur, must in backing out strike the *rostellum,* a small viscid knob to which the pollinia are attached. These adhere to the head of the insect, and parts of them are left on the viscid stigmas of the flowers subsequently visited.

Insect-pollination may also be secured, without irregularity, by *heterostyly.* In the Primrose, for example, there are two kinds of flower, one possessing long styles, with anthers placed deeply in the corolla-tube, while in the other a short style co-exists with anthers at the mouth of the tube. This arrangement is evidently conducive to cross-pollination. If, for instance, an insect dusted with pollen from a short-styled form visits a long-styled flower, the stigma will be first encountered, and upon this some pollen will probably be deposited.

Intruding insects are kept out by various devices, as *chevaux-de-frise* of hairs, sticky surfaces, and slippery slopes.

(*c.*) *Water-pollinated* flowers are seen in some aquatic forms. In *Valisneria spiralis* the plants are diœcious, and the female flowers possess spiral stalks, which, when they are mature, uncoil. Thus raised to the surface, they are pollinated by the agency of the water, which floats the small male flowers, that when ripe become detached, into contact with them.

(*d.*) *Bird- and Snail-pollinated* flowers are also known.

Self-pollination is sometimes secured by the arrangement of parts, often only as a last resource, should cross-pollination fail. In some plants inconspicuous *cleistogamous* flowers only suited for self-pollination are possessed together with normal ones, as in the Dog-Violet.

Fertilization.—This succeeds pollination. The pollen-grains placed on the stigma emit pollen-tubes (*compare p.* 75), which traverse either a channel or loose conducting tissue in the style, in order to reach the ovules. The micropyle of the ovule is then entered, and one of the nuclei in the end of the pollen-tube passes in and fuses with the oosphere, thus fertilizing it. Some flowers are *self-sterile*—*i.e.*, if pollinated with their own pollen no effect ensues.

4. Contractility.—Streaming movements are visible in the protoplasm of many cells, especially those of hairs. Parts of plants may also exhibit marked movements, as, for example, in the Sensitive Plant, but these are not effected like muscular movements.

5. Irritability and Spontaneity.—The leaves of the Sensitive Plant close if handled, as the result of the mechanical stimulus of contact. Other stimuli may affect certain plants. Thus the knotted tentacles with which the leaves of the Sundew are covered gradually fold over on the contact of certain nitrogenous substances, as, for example, minute insects, which act chemically on them. Spontaneity is shown in the continuous movements of growing parts—in the twining movements—*e.g.*, exhibited by climbing plants.

GENERAL CONDITIONS OF PLANT LIFE.

The different functions of plants are dependent upon **1. Temperature.**—For any particular plant, and, indeed, for each function of that plant, there are *minimum* and *maximum* temperatures, which bound the possibilities of activity. Between these is an *optimum*, or most favourable temperature. In this climate the minimum and maximum temperatures may be taken at 32° and 122° F. or thereabouts, while a common optimum is 80° F. If the limits are overstepped too far, death ensues; but this largely depends upon the amount of moisture in the plant. If this is present in small quantities only, extremes are better withstood than would otherwise be the case.

2. Light is necessary to green plants, as without it they are unable to utilize the air's carbon dioxide by means of their chlorophyll. Generally speaking, this substance cannot be formed in the absence of light; but exceptions are found in the case of seedlings of Pinus and the leaves of Ferns. Plants kept in the dark become of a yellowish colour, and are said to be *etiolated*. The protoplasmic basis or framework of the chlorophyll-corpuscles is formed, however, and through this is diffused a yellow colouring-matter, *etiolin*, similar in composition to chlorophyll, and capable of being converted into it in the presence of light.

A retarding influence on growth is exerted by light. This is familiarly illustrated by the rapid growth in the dark of shoots from potatoes which are kept moist and warm. In this case the starch, &c., stored up in the tuber as reserve material, obviate the necessity for a supply of food from the exterior. Plants kept in a window-box curve towards the light owing to its retarding influence, because growth on the dark side is more vigorous than on the other. The same thing may be observed in colourless plants—*e.g.*, in the gonidiophores of *Mucor*. This phenomenon is termed *positive heliotropism*.

3. **Gravity** determines to a large extent the downward growth of roots and the upward growth of stems, or *positive* and *negative geotropism*. This can be proved by making plants rotate slowly, the direction of rotation being constantly changed and gravity thus neutralized. Under these circumstances, the roots and stems show no definite direction of growth.

4. **Electricity** probably plays an important part in growth, as electric currents taking various courses have been demonstrated in living plants. Currents artificially sent through a root have been found to retard its growth.

DEVELOPMENT.

The development of the **oophyte** has already been dealt with (*p.* 105), and that of the **sporophyte** may now be considered.

After fertilization has been effected, the flower withers and the ovules commence developing into *seeds*. This is accompanied by the formation of a *fruit*, which is the modified ovary. In many cases, other structures take a share in its formation, when it is spoken of as a *spurious* fruit, or *pseudocarp*.

(1.) The first change that occurs is the formation of a mass of *endosperm* within the embryo-sac, which enlarges in size, and in most cases entirely absorbs and displaces the tissue of the nucellus. Sometimes, however, no endosperm or but little appears. The nucellus may then become filled with reserve material for the growth of the embryo, which in this case is called *perisperm*. The embryo is often a small body enclosed in the endosperm, or, as in Grasses, placed on one side of it; but in a great many Dicotyledons the cotyledons of the embryo absorb the surrounding reserve-material, for which they themselves then serve as receptacles.

The integuments of the ovule develop into coats for the seed.

(2.) *Development of the Embryo.*—This takes place rather differently in *Monocotyledons* and *Dicotyledons*. In the latter, a typical

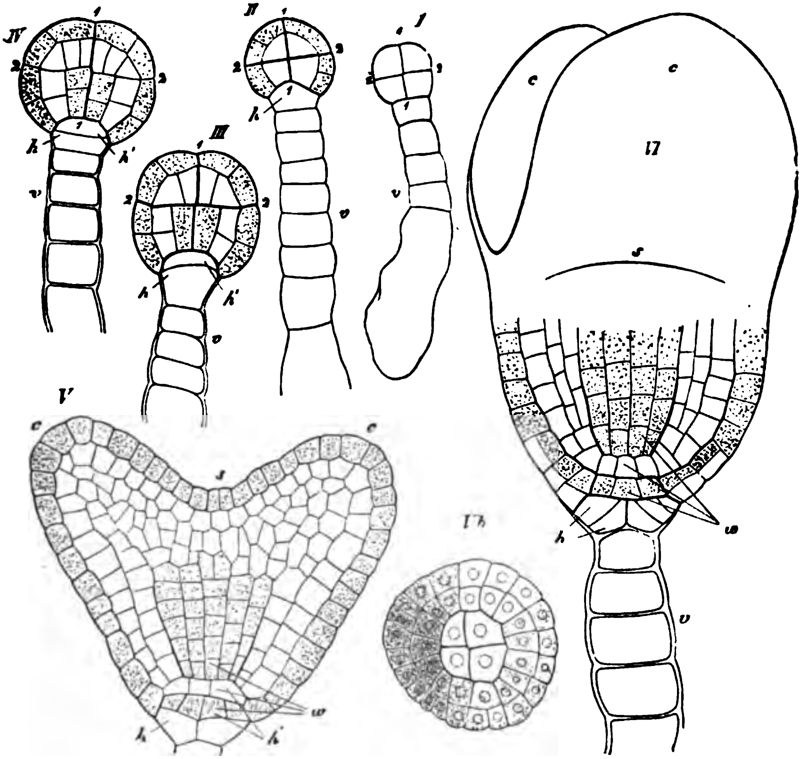

Fig. 74.—Development of Shepherd's Purse (from *Sachs* after *Hanstein*).—I. to IV., Various stages of development; *Vb*, apex of root seen from below; 1,1, 2,2, first divisions of embryo; *h*, hypophysis; *v*, suspensor; *c*, cotyledons; *s*, apex of stem; *w*, root; dermatogen and plerome are shaded.

example is the Shepherd's Purse (*Capsella bursa-pastoris*). The oospore elongates, and growing away from the micropyle into the embryo-sac, develops into a row of cells. The end-cell (*i.e.*, away from micropyle) becomes the embryo, while the others form the *suspensor*. The embryo-cell swells up to the spherical form, and is then divided into octants by three successive walls (Fig. 45, I., 1 and 2, third wall in plane of paper). From these peripheral cells are cut off to form the *dermatogen* of the embryo (shaded margin in Fig. 74, II., III., &c.), and inside this, *plerome* and *periblem* are afterwards differentiated (III., &c., plerome shaded, periblem unshaded). The suspensor-cell next the embryo (*i.e.*, *hypophysis*) divides into two others (*h*, *h'*) by a transverse wall. The one adjoining the embryo assists in its formation. The cotyledons and plumule are produced from that part of the embryo furthest away from the suspensor (above 2—2 in the figure), and the former are seen growing out in V. and VI. The rest of the embryo becomes the radicle, the tip of which is made up of cells derived from the hypophysis.

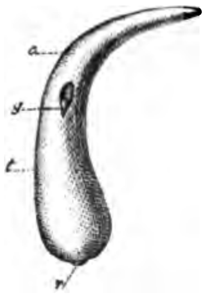

Fig. 75.—Embryo of Monocotyledon.—*c*, Cotyledon; *g*, growing point of stem; *r*, radicle.

In *Monocotyledons* the single cotyledon is formed by the free end of the embryo (Fig. 75, *c*), and the growing point of the stem originates laterally. The radicle is developed as before.

(3.) *a*. The most important characters of the seed have been already mentioned, and consist in the relations that obtain between the embryo and the endosperm. The latter may sometimes be very hard, as in the Date, where it is composed of cellulose, making up the greater part of the "date stone." It may also contain a central cavity, as in the Cocoa-nut, the edible part of which is made up of endosperm, in one end of which the small embryo is imbedded. The condition of the seed-coats varies according to the nature of the fruit. They are soft, if the fruit is hard, and *vice versâ*, and may also be soft, if the endosperm is of very firm texture. The exterior of the seed usually possesses a distinct epidermis, which may be smooth or raised into various markings. In other cases, hairs may grow out, either in great abundance, as in the Cotton-tree, where they form cotton, or in a tuft, as in the Willow-herb. In some cases, *e.g.*, Linseed, the epidermal cells are convertible into mucilage. The point which marks the attachment of the funicle is known as the **hilum**. Near this the micropyle can be made out in inverted and bent seeds, and at the opposite end in straight seeds. The name *aril* may be applied to all the growths external to the seed-coating developed from it or from the funicle, as, for example, the hairs above-mentioned, but the term is more specially given to envelopments which can be readily detached. The "mace" which covers the Nutmeg is an example of this.

b. **Fruit.**—This has been already defined, as also the term "pseudocarp," and both may now be described.

1. *Pseudocarps* (Spurious Fruits).—These are formed by the development of very various parts in the neighbourhood of the ovary. The Fig. (Fig. 76), for example, is a succulent flower stalk, the end of which is hollowed out, and contains numerous minute male and female flowers attached to its inner side. In the Mulberry (Fig. 77), the flowers also grow in groups, and the perianths of each group become juicy, forming a single pseudocarp. In the Strawberry, again, the flesh is merely the dilated torus, upon which many small dry fruits are borne. The same structure, in this case hollowed out, is the succulent part of the Rose-fruit, or hip, within which the dry fruits are contained. A

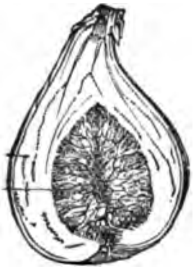

Fig. 76.

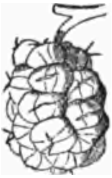

Fig. 77.

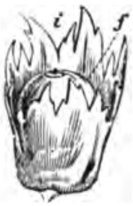

Fig. 78.

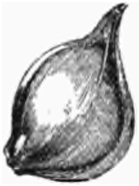

Fig. 79.

Fig. 76.—Section of Young Fig.—*r*, Succulent flower stalk; *f*, flowers placed in internal cavity.
Fig. 77.—Pseudocarp of Mulberry.
Fig. 78.—Hazel Nut.—*f*, Fruit; *i*, bracts.
Fig. 79.—Achene of Buttercup.

somewhat similar example is found in the Apple, &c., and here a difference of texture marks the boundary between the walls of the ovary and the swollen torus.

2. *True Fruits.*—These are classified as dry or succulent, and sub-divisions are formed on the characters afforded by dehiscence or its absence. In all cases the modified wall of the ovary is known as the *pericarp*, in which three layers—epicarp, mesocarp, and endocarp—may frequently be distinguished.

A. Dry Fruits.—Pericarp hardened or tough and destitute of cell-sap.

1. **Indehiscent.**—The seeds, which possess thin coats, remain in the pericarp till germination.

(*a.*) *One-seeded.*—Under this heading are included the *nut* (Fig. 78), as the Hazel, in which the pericarp is firm and sclerenchymatous, and also the *achene* (Fig. 79) and *caryopsis*, in which the pericarp is thin and tough. In the former the pericarp can be separated from the seed-coats—*e.g.*, Buttercup; but in the latter this is not the case—*e.g.*, Wheat and Dandelion.

(*b.*) *Two or more-seeded.*—These generally divide into constituent mericarps, each of which resembles a nut or achene. Examples of these *split-fruits* are Carraway and Geranium (Fig. 80). When the mericarp is winged it is a *samara*, as in the Sycamore (Fig. 81).

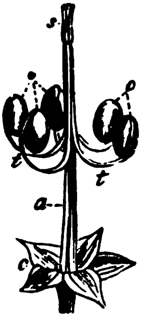

Fig. 80.—Split-Fruit of Geranium.—The constituent mericarps are separating.

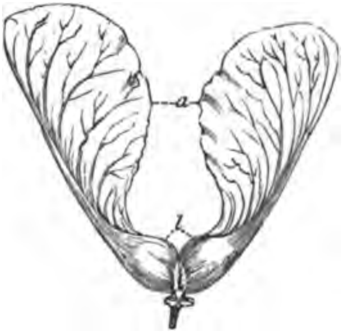

Fig. 81.—Samaras Sycamore.

2. Dehiscent or Capsular.—The pericarp dehisces to liberate the seeds, which have firm seed-coats and are often numerous.

(*a.*) *Longitudinal Dehiscence.*—The *follicle* is a single carpel, which splits along the ventral suture, as in the Columbine (Fig. 82). The *legume* (Fig. 83) is similar, but splits along both sides, as in the Pea and Bean. The *siliqua* (Fig. 84) is made up of two carpels, and its cavity is divided into two halves by a longitudinal partition, the *replum*, from which the rest of the fruit separates in a valvular manner.

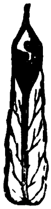

Fig. 82.

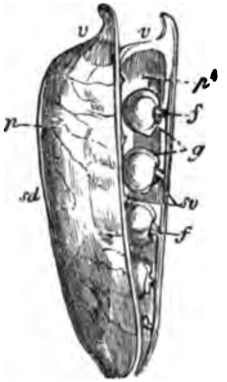

Fig. 83.

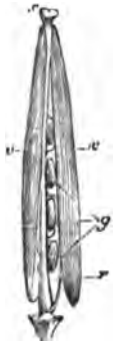

Fig. 84.

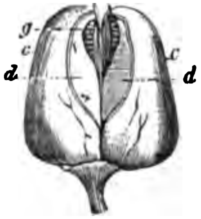

Fig. 85.

Fig. 82.—Follicle of Columbine.

Fig. 83.—Legume of Pea.—*sv*, Ventral suture.

Fig. 84.—Siliqua of Wallflower.—The valves, *v v*, are seen separating from the replum, *r*; *g*, ovules; *s*, stigma.

Fig. 85.—Septicidal Capsule of Foxglove.

The *capsule proper* is derived from a syncarpous ovary, which may contain one or more cavities. In the latter case the partitions (septa) may themselves split, when the dehiscence is *septicidal* (Fig. 85), or the walls of the capsule may split midway between them, when it is *loculicidal* (Fig. 86). *Septifragal* (Fig. 87) dehiscence resembles the latter, but the dissepiments remain united together in the middle of the fruit. If the capsule contains a single cavity, it may split in either of the two first-mentioned ways.

(*b.*) *Transverse Dehiscence.*—The fruit in this case is a *pyxidium* (Fig. 88), the upper part of which separates like a lid.

(*c.*) *Porous Dehiscence.*—In these *pore-capsules* (Fig. 89) small openings are formed for the exit of the seeds.

B. Succulent Fruits.—Some or all of the pericarp becomes fleshy.

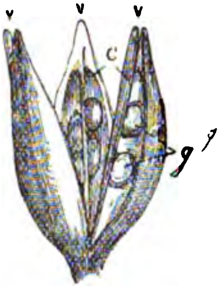

Fig. 86.

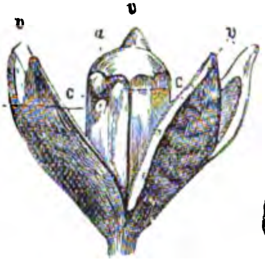

Fig. 87.

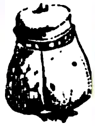

Fig. 88.

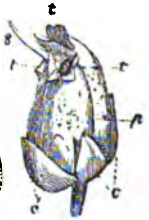

Fig. 89.

Fig. 86.—LOCULICIDAL CAPSULE OF HIBISCUS.
Fig. 87.—SEPTIFRAGAL CAPSULE.—*v*,*v*, Valves; *c*,*c*, septa.
Fig. 88.—PYXIDIUM OF HENBANE.
Fig. 89.—POROUS CAPSULE OF SNAPDRAGON.—*t*,*t*, Pores.

1. Indehiscent.—The *stone-fruit* (drupe) possesses a thin epicarp, a fleshy mesocarp, and a hard, firm endocarp, which forms the wall of the stone—examples, Cherry, Plum, &c. The Blackberry and Raspberry are aggregates of minute stone-fruits. The *berry* possesses a tough or firm epicarp, while the rest of the pericarp is succulent, and encloses the seeds, which possess firm seed-coats. Examples are the Gooseberry, Cucumber, and Date. The fruits of the Orange, Lemon, &c., somewhat resemble the preceding, but receive the special name of *hesperidium,* in which the coloured part of the peel is epicarp, the white portion mesocarp, and the pulp a special development of endocarp.

2. Dehiscent.—The pericarp is never pulpy. Two common examples are the Chestnut, which possesses what may be described as a succulent capsule, and the Walnut, in which part of the pericarp dehisces, while the endocarp forms the firm shell.

PROTECTION AND DISPERSION OF THE SEED.

The **Seed** is *protected* in a variety of ways when ripening—for example, by a firm shell, as the Hazel, or by the inedible nature of the unripe fruit. The same end is sometimes subserved by movements. The Dandelion lowers itself, and remains close to the ground for about twelve days, while its fruit is maturing, and Water-lilies sink to the bottom. In *Valisneria* the spiral stem of the female flower (*compare p.* 110) is wound up, and draws it downwards for the same purpose.

The *dispersion* of seeds is assisted by numerous active and passive arrangements. In the former case special movements are performed. The Dandelion raises itself from the ground when its fruits are ripe, and in a number of plants *seed-throwing* takes place. Thus, the capsules of the Dog-Violet separate into three diverging valves, in each of which is a row of smooth seeds. These are clasped by the edges of the valve, and its contraction ultimately causes them to be shot for some distance (ten or more feet). In the split-fruit of the Geranium (Fig. 80, D) five mericarps are present, produced upwards into elastic rods attached to the apex of the fruit. These act as springs, by which the mericarps are thrown to some distance. The pods of the Broom and Vetch spring open when ripe, and the seeds are scattered with some violence. Another interesting example is the Squirting Cucumber, which contains a large number of seeds enclosed in pulp. The ripe fruit is in a high state of tension, owing to the absorption of fluid, and injury at the stalk-end causes the seeds to be squirted out as far as twenty feet with considerable violence.

Some few plants are *heterocarpic*, possessing fruit of two kinds, one of which is specially adapted for *self-sowing*, being placed near the ground, into which it may even be forced by the growth of the flower-stalks. Passive distribution is mainly effected by the wind and by animals. In the former case the fruit or seeds may possess wings (Fig. 81), as frequently happens in trees, or a crown of feathery hairs may grow out. These sometimes represent the calyx (as in Dandelion), when they are termed *pappus*. In porous capsules the seeds are shaken out by the wind, and to prevent them from simply falling out, the pores are in the upper part of the capsule (Fig. 89). In the case of animals, the fruit may be eaten, the seeds being protected so as to escape digestion. With this end fruits possess bright colours, and they become edible when the seeds are mature. Many fruits possess hooked appendages, by means of which they can stick to the coats of animals.

Arrangements of this sort are only found on plants the height of which renders them likely to be brushed against.

Germination.—Seeds remain in a dormant condition for a longer or a shorter time. They can often retain the power of germination for a very long period. Certain general external conditions are essential in all cases, if germination is to be effected. In the first place, a supply of free oxygen is absolutely necessary, owing to the activity of respiration. A supply of moisture is also requisite, and the temperature must be within certain limits, the *optimum* varying according to the plant. Reserve-materials are stored up in seeds, and upon these the young plant draws before it develops chlorophyll and begins to obtain food from the exterior. These reserve-materials are principally starch, oil, and proteid substances in the form of minute bodies known as *aleurone grains.*

The first step in germination is the rupture of the seed-coat opposite to the radicle, which then grows downwards. The plumule commences to grow upwards and unfold rather later. When endosperm or endosperm and perisperm are present, the cotyledon or cotyledons absorb it. This is the case, for example, in Grasses, where the cotyledon is termed the *scutellum.*

The methods of Germination are classified into *hypogean* or *epigean*, according to the behaviour of the cotyledons. In the former case these remain below ground and serve as stores of nutriment (*e.g.*, Scarlet Runner), while in the latter, where reserve-materials are scanty, they are carried up by the elongation of the hypocotyl, become green, and perform the typical leaf-functions (*e.g.*, Sunflower).

CHAPTER VII.—COMPARATIVE VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

In passing up the scale from the very lowest to the highest plants, the main principles exemplified are **physiological division of labour** on the one side, going hand in hand with **morphological differentiation** on the other.

A unicellular plant like *Protococcus* performs, as we have seen all the functions of life (*p.* 24); but even in this case, different parts of the plant-body are apportioned off for the performance of special duties, and, in accordance with this, exhibit special structure.

The essential part of the cell is its *protoplasm*, and the cell-wall is formed by this to serve as a protective structure. The zoospores of Protococcus, which possess no cell-walls, perform the same functions as those which possess them. The division of labour is mainly exemplified in this form in the case of contractility, which function is more particularly relegated to the flagella and the projection of clear protoplasm whence they arise. It is also more than probable that the red pigment-spot is especially adapted for being acted upon by light.

The *Yeast-plant* resembles Protococcus in being unicellular, but its physiology is largely modified by the absence of chlorophyll. Protococcus and Yeast serve as starting-points from which to consider green and colourless plants respectively. One of the most important advances upon them is the attainment of the *multicellular* condition. If the gemmation-products of Yeast or the fission-products of Protococcus were to remain united together, this condition would be reached. *Spirogyra*, although multicellular, does not exhibit any great advance, except in reproduction, as the individual cells are, at least to a large extent, independent of one another. In the other examples described, this is not the case, and the cells exhibit more or less diversity in accordance with the division of labour. The final result of this is the formation of *tissues*, *i.e.*, aggregates of similar cells, adapted for the performance of special functions.

As all plants (and indeed all organisms), low or high, perform the *same* functions, it is evident that the physiological heads of nutrition, destructive metabolism, reproduction, contractility, and irritability and spontaneity, are well-adapted for comparative purposes. To these must be added, for the sake of convenience, the subordinate head of *protection and support*, which is, it must be remembered, on a very different footing from the others, not being like them *primary*.

1. Protection and Support.—As mentioned above, protection is subserved by the cell-wall, the efficiency of which in this respect may be increased by thickening and chemical change. In many cases among multicellular plants, aggregation into two or more layers still further increases the effect. The walls of the hyphæ in *Mucor* are impregnated with oxalate of lime, and this plant also presents instances of special protection for reproductive bodies in the firm sporangium for the endogonidia, and the thickened outer coats for the zygospores.

In *Penicillium* the developing sporophyte is protected by the fusion of numerous hyphæ, the walls of which are so much thickened as to earn for the fruit the name of *sclerotium*. *Protococcus*, like many lower organisms, and also Mosses, can bear a large amount of desiccation, owing to the protection afforded by the cell-wall. The zygospores of *Spirogyra* are well protected by thick coatings like those of Mucor, and this is necessary, since both remain for some time in a dormant state as *resting-spores*.

Chara is protected to some extent by an external incrustation of carbonate of lime; but this cannot be of very great moment, since it is absent in the closely allied *Nitella*. The advance of histological differentiation is marked in *Fucus* by the distinction between rind and medulla. The compact nature of the former fits it for protection, which is necessary in this case to prevent desiccation when the plant is left uncovered by the tide. The brown colouring-matters present may also have something to do with this. Here, for the first time, is seen the *trichome*, which, in the Flowering Plant, plays an important part in protecting flowers from the attack of unwelcome insects ("unbidden guests"), either by forming, as we have seen, *chevaux-de-frise*, or by secreting a sticky substance.

In the *Moss*, the epidermal cells are very strongly thickened and cuticularized, accounting for the power possessed of standing a very large amount of drying without injury.

The *Fern* commences, as it were, a new epoch of differentiation, and presents an immense advance upon the Moss in the three well-developed systems of tissue which it possesses. The epidermis as the external tissue naturally subserves protection, as, indeed, previously seen in the Moss. The development of *sclerenchyma* in the ground-tissue answers the same end, and also, with the lignified elements of the xylem, assists in supporting the plant, an important matter where any great size is attained. The root is an important organ of support in *Pinus* and the *Flowering Plant*.

In *Pinus* and the *Dicotyledonous Flowering Plant* the rupture of the epidermis in thickening stems and roots is made up for by the development of *cork*, in the cortex or pericambium, as the case may be. Here also the supporting function of the lignified xylem reaches its maximum.

In the Flowering Plant protection may be afforded by thorns and spines, which arise by the modification of organs usually performing very different duties—*e.g.*, leaf spines of Gorse, or as special developments, *e.g.*, the prickles of the Rose.

2. Nutrition.—In *Protococcus*, the chlorophyll is distributed through most of the cell, except internally and in the zoospores, where the especially contractile part is colourless. In *Spirogyra*, it is limited to the spiral band, where alone carbon dioxide can be broken up, while starch is formed solely by the chlorophyll-bodies. From *Fucus* upwards, chlorophyll is only found in chlorophyll-corpuscles, which in the highest plants are most abundant in the mesophyll of the highly differentiated leaves. The absorption of water and salts is effected by the general surface of the body in the *unicellular forms*, *Spirogyra*, and *Fucus*; in *Chara* and the *Moss* mainly by rhizoids, while in the *Fern*, *Pinus*, and the *Flowering Plant*, true roots are developed, the root-hairs and thin-walled epidermal cells of which subserve this end.

The colourless plants utilize more complex food than the others, and in *Penicillium* the submerged hyphæ absorb nutriment from the substratum, while a high colourless plant which lives parasitically—*e.g.*, the Dodder, becomes intimately connected with the tissues of its host. Green plants, such as the Pitcher-plant, may partly depend on complex food, and they possess various remarkable structures, in this case pitchers, adapted for securing insects.

Circulation of liquids in the undifferentiated forms can only take place by diffusion from cell to cell; but with the appearance of vascular bundles, first foreshadowed in the Moss, special channels are provided, and the same may be said of laticiferous tissue. In the vascular plants, channels are also provided for the circulation of gases; such are, more particularly, the intercellular spaces in the mesophyll, and the cavities of the tracheides and vessels, which last do not under ordinary circumstances contain liquid.

3. Destructive Metabolism.—(1.) **Respiration** is essential to all plants alike, except *Yeast* and *Bacteria*, where fermentation, in some way not understood, seems to make up for it. Respiration is quite independent of chlorophyll; but in green plants is best observed in darkness, as the carbon dioxide of the air cannot then be broken up, and there is therefore no evolved oxygen to mask the carbon dioxide given off as a waste-product.

(2.) **Excretion** of nitrogenous waste is rarely direct, but does occur in higher plants—*e.g.*, May. In other cases, such waste is indirectly got rid of by being stored in bark, &c., which becomes detached.

4. Reproduction.—(1.) **Vegetative Reproduction** is seen in the gemmation of *Yeast* and the fission of *Bacteria*, *Protococcus*, and *Spirogyra*. It may also occur, under unfavourable circumstances, in *Mucor*. Several methods of vegetative reproduction are exhibited by *Chara*, a very large variety by the *Moss*. This phenomenon is also seen in the *Fern*, and is shown in a variety of ways in the *Flowering Plant*.

(2.) **Asexual Reproduction** is seen in the formation of *gonidia* and *spores*. *Bacteria*, at least some of them, produce vast numbers of spores under unfavourable conditions, which also cause *Yeast* to develop *endogonidia*. These last are formed in *Mucor* in the commonest method of reproduction known. The usual way in which *Penicillium* propagates is by *stylogonidia*. *Protococcus* produces motile *zoospores*. The *Moss* and *Fern* produce spores of one kind in capsules and sporangia of complex structure. The latter are developed from the epidermis, and are therefore trichomes.

In *Pinus* and the *Flowering Plant* spores of two kinds are produced, male and female, or *microspores* and *macrospores*. These occur in *flowers*, which are very complex in the latter type.

(3.) **Sexual Reproduction** is first found in the form of **Conjugation**, as in *Mucor* and *Spirogyra*, where the male and female elements are similar in shape and size. They are simple *cells*, and fuse together to produce a *zygospore*.

In *Penicillium* the two elements are alike in shape, but the contents of the male antheridium pass over into and *fertilize* the carpogonium.

Fucus exhibits sexual reproduction alone, and that in a very typical manner. Male and female *organs*, in this case trichomes, are present, which produce respectively small motile *male cells*, spermatozoids, and passive, relatively large *female cells*, the oospheres. One or more (?) male cells fuse with each female cell, which is now *fertilized*, and can develop into a new plant.

Chara possesses male and female sexual organs of similar physiological but different morphological characters to the above.

The *Moss*, the *Fern*, and *Pinus* agree in the characters of their female organs; these are *archegonia*, each containing a single oosphere, from which, before fertilization, a small *ventral canal-cell* (polar-cell) is cut off. The archegonium of *Pinus* is, however, much reduced, and its male organs are not, as in the Moss and Fern, antheridia producing motile spermatozoids, but pollen-tubes, in which nuclei represent male cells. The *Flowering Plant* resembles Pinus in the characters of its male organs, but its female organs are still further reduced, and represented only by the *egg-apparatus*. Conspicuous flowers are present. That flower-leaves = modified foliage leaves, may be told by the gradations which occur, as in Fig. 61.

Self-fertilization is prevented and *cross-fertilization* secured in a number of different ways. The latter is beneficial for reasons as yet unknown. The methods are based upon—(1) Position of male and female organs, (*a*) on different plants (*Fucus*, most *Mosses*, and many *Flowering Plants*); (*b*) in different parts of the same plant (some *Mosses*, *Pinus*, some *Flowering Plants*); (*c*) together, but in such a way that self-fertilization is impossible (many *Flowering Plants*). (2) Maturation of male and female elements at different times in the same plant (*Chara*, many *Flowering Plants*). (3) Action of external agents—(*a*) Wind (*Pinus*, many *Flowering Plants*); (*b*) Insects, in connection with which the irregular shape, colour, scent, nectar, &c., of the flowers, possessed by many *Flowering Plants* are developed; (*c*) Water, &c., in various *Flowering Plants*.

Alternation of Generations.—This has been sufficiently discussed in the preceding parts of the work, but attention must be here called to the relatively immense importance and size of the sporophyte in the *Fern*, *Pinus*, and the *Flowering Plant*. In the two last, the embryo sporophyte remains in a dormant state for some time within the **seed**, which is the most characteristic structure possessed by higher plants. The seeds are scattered and distributed by various means discussed on page 119.

The following table will serve as a reminder of the relations between the oophyte and the sporophyte :—

	SPOROPHYTE.		OOPHYTE.	
Mucor, ...	Pro-mycelium.		Ordinary plant.	
Penicillium, .	Fertile hyphæ of sporocarp.		Ordinary plant.	
Chara, ...	Pro-embryo.		Ordinary plant.	
The Moss, . . .	Sporogonium.		Ordinary plant.	
The Fern, . . .	Ordinary plant.		Prothallus (bisexual, with antheridia and archegonia).	
Higher Vascular Cryptogam, e.g., *Selaginella*,	Ordinary plant producing:—		Rudimentary prothalli.	
	Male.	*Female.*	*Male.*	*Female.*
	Microspores (in microsporangia).	Macrospores (in macrosporangia).	(Within the microspore.)	(Within the macrospore.)
Pinus, ...	Ordinary plant :—			
	Pollen-grains (in pollen-sacs).	Embryo-sacs (in ovules).	Cells in pollen-grain with pollen-tube (antheridium).	Endosperm with archegonia.
Flowering Plant, .	Ditto.	Ditto.	Ditto.	Antipodal cells and egg-apparatus.

5. Contractility.—In the zoospores of *Protoccocus* and the spermatozoids of *Fucus*, *Chara*, the *Moss*, and the *Fern*, **flagella** are possessed, by the agency of which locomotion is effected. **Streaming** movements are observable in the cells of *Spirogyra*, and the more general movements of **rotation** in those of *Chara*.

In the *Flowering Plant*, not only may streaming take place in the protoplasm, *e.g.*, of hairs, but movements of a more extensive character may occur. This is seen very markedly in the growing stems of *climbing plants*, and in the movements of forms like the *Sensitive Plant*. In the latter, and similar case where movement results at once on the application of a stimulus, the "continuity of protoplasm," demonstrated in parts of certain plants, probably has an important bearing. That is to say, it has been shown that the protoplasm in adjacent cells may be permanently united by fine threads of the same material passing through the cell-walls. For effecting movements such an arrangement is invaluable, and this kind of continuity seems to foreshadow the muscle fibres of animals. Movements like those of the Sensitive Plant are effected, however, by expulsion and re-absorption of fluid in certain parts, and not like muscular movements.

6. **Irritability and Spontaneity.**—The zoospores of *Protococcus* and the spermatozoids of *Fucus*, *Chara*, the *Moss*, and the *Fern* exhibit this in the most obvious manner. The movements of the higher plants are also due in part to external stimuli, and in part to internal stimuli, in which latter case they are "spontaneous." The "continuity of protoplasm" has here also an important bearing, and the nerves of animals seem prefigured.

CLASSIFICATION OF PLANTS.

(*For general remarks on classification, see p.* 7.)

Group I.—Thallophytes.

Plant-body a *thallus* (*stem* and *leaf* not, or little differentiated; *roots* unrepresented, or represented by rhizoids only).

Sub-Group 1.—Algæ (*Protococcus*, *Spirogyra*, *Fucus*, and *Chara*).

Chlorophyll present (and therefore—*light* necessary; *carbon dioxide* serves as source of carbon; *oxygen* evolved).

Sub-Group 2.—Fungi (*Yeast*, *Bacteria*, *Mucor*, and *Penicillium*).

Chlorophyll absent (and therefore—*light* unnecessary; *carbon dioxide* will not serve as source of carbon; *oxygen* not evolved).

Group II.—Bryophytes (the *Moss*).

Alternation of generations well-marked. *Sporophyte* attached to and dependent on oophyte. *Stem* and *leaf* (of *oophyte*) differentiated*; *roots* represented by rhizoids.

Group III.—Vascular Cryptogams† (the *Fern*).

Alternation of generations well-marked. *Sporophyte* large, independent, and well developed; *stem* and *leaf* well differentiated; *roots* (nearly always) present; *vascular bundles* and distinct *epidermis* present. *Oophyte* small, independent, but thalloid; *female organs* archegonia.

Group IV.—Phanerogams (*Pinus*, the *Flowering Plant*).

Alternation of generations well-marked. *Sporophyte* differentiated as in Group III., but of even greater relative importance; *spores* of two kinds. *Oophyte* extremely small, represented by male and female prothalli. *Male prothallus* free, but minute; *male cells* never spermatozoids (as in Groups II. and III., and often in Group I.), but represented by nuclei in pollen-tube (antheridium). *Female prothallus* small, imbedded in and dependent on sporophyte. A *seed* always developed.

Sub-Group 1.—Gymnosperms (*Pinus*).

Ovules (macrosporangia) not enclosed in an ovary. *Female prothallus* well-developed, compared to Sub-group 2; *Archegonia* present, but rudimentary.

Sub-Group 2.—Angiosperms (the *Flowering Plant*).

Ovules enclosed in stigma-bearing ovary. *Female prothallus* extremely rudimentary; *archegonia* never present; *secondary endosperm* produced after fertilization.

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* A *thallus* in some Liverworts.

† The first three groups are often collectively termed *Cryptogams*. No *conspicuous flowers*.

PART II.

ANIMAL MORPHOLOGY AND PHYSIOLOGY.

CHAPTER I.—PROTOZOA.

§ 1. AMŒBA (Proteus Animalcule).

This is a microscopic animal, varying much in size. It is generally found on the surface of the mud in fresh-water pools, and also occurs on damp earth, in organic infusions, &c.

MORPHOLOGY.

1. External Characters.—The form of an active Amœba is constantly changing (as its name is meant to show), but it is always irregular. The semi-fluid, transparent protoplasm of which the body is wholly composed is produced into bluntish lobes, *pseudopodia*, which vary continually in number and shape. In most Amœbæ these can be emitted from any part of the body.

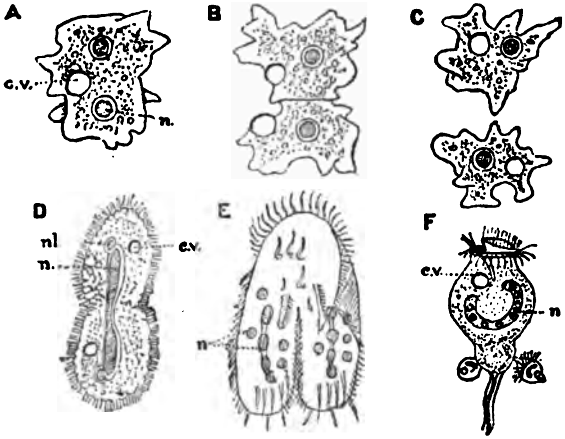


Fig. 90.—Amœba and Vorticella (from *Haddon*, after *Howes*, and *Stein*), enlarged.—A-C, Stages in fission of *Amœba* ; D and E, Fission of other Protozoans ; F, Conjugation of *Vorticella*. *c.v.*, Contractile vacuole ; *n*, nucleus.

2. Structure (Fig 90, A).—An outer perfectly transparent *exoplasm* can be distinguished from a more granular internal *endoplasm.* The exoplasm is apparently firmer than the endoplasm, but there is no clear line of demarcation, and as part of the body may be outside one moment, and inside next, the apparent difference is probably caused by a tendency of the granules to collect in the centre.

Within the granular portion two important structures are present:—(1) A rounded or oval mass of denser protoplasm than the rest, the *nucleus* (*n*) (endoplast). This may contain a smaller particle, the *nucleolus* (endoplastule). (2) The *contractile vacuole* (*c.v.*), a spherical space with fluid contents, which varies much in size, owing to the contraction of its walls. There may be more than one.

More or less food is usually present in the endoplasm, and the so-called *food-vacuoles* are parts of this surrounded by a clear layer of fluid. Spaces containing gas, *gas-vacuoles,* have been observed in some examples.

PHYSIOLOGY.

The functions carried on by Amœba and all other animals are the same as those previously enumerated for plants (*p.* 24-26), and may be considered under the same headings.

1. Nutrition.—The food of Amœba consists of small organisms. Its pseudopodia come into contact with these, and, so to speak, engulf them. All parts of the body alike serve for the reception of food. The complex chemical composition of the substances utilized, and their *ingestion* in the solid state are worthy of notice, as typical *animal* characteristics. Each mass enters the body surrounded by a small quantity of water, and a food-vacuole is thus constituted. The temporary breach in the protoplasm is, of course, at once and readily closed up. Within the body, mechanical and chemical influences are brought to bear upon the food. It is subjected, on the one hand, to slow rotation in the endoplasm, while on the other, juices, *secretions,* reduce the digestible portions to a state of solution, or fine division. They are then *assimilated,* that is, built up into living protoplasm. The indigestible remnants are thrown out at any part of the body.

Encystment.—If conditions of temperature or food-supply are unfavourable, Amœba possesses the power of assuming a spherical form, at the same time secreting a firm structureless coating or *cyst*. This appears to be of a horny nature, and is a very considerable protection.

2. Destructive Metabolism.—The complex protoplasmic molecules are constantly breaking down into simpler substances, and kinetic energy is thus gained. This process is, as a rule, far more rapid in animals than in plants, and greater activity is consequently displayed.

The products of destructive metabolism are:—

a. **Secretions**, which are utilized in some way before passing out of the body. It is probable, for example, that Amœba *secretes* something corresponding to the digestive juices of other forms, which acts chemically upon the food.

b. **Excretions** (waste-products), which pass out of the body at once. These are—water, carbon dioxide (CO_2), and compounds of ammonia.

Destructive metabolism is, practically, a process of *oxidation*, the result being that animals, like most plants, require a supply of *free oxygen*. As before (*p.* 13), the term **Respiration**, or breathing, is applied to the taking in of oxygen with a concomitant excretion of carbon dioxide (and water).

The *contractile vacuole*, which contracts and expands rhythmically, appears to communicate with the exterior. It probably serves the double purpose of pumping in oxygenated water and pumping out waste-products. The general surface of the body is also doubtless respiratory, oxygen diffusing in and carbon dioxide diffusing out.

3. Reproduction (Fig. 90, A–C).—This is asexual, and usually effected by *binary fission*, the animal splitting into two equal parts. The nucleus elongates, becomes dumb-bell-shaped, and separates into two, each half being surrounded by a moiety of the protoplasm, which has meanwhile been gradually constricted.

More rarely, *gemmation*, or budding, occurs, small pieces of the protoplasm being separated off. The parent nucleus does not share in this process, each bud developing a new nucleus within itself.

4. Contractility.—The movements of Amœba are effected in virtue of this property, irregular contractions of the protoplasm leading to the formation of pseudopodia. The exoplasm is elevated into a hyaline knob, into which, as it increases in size, the endoplasm enters with a rush. An anterior *progressing region*, actively flowing out into pseudopodia, and a more passive *following region*, can often be made out in a moving Amœba. These regions are in ordinary examples determined by the direction of movement, and simply correspond to the anterior and posterior ends for the time being. There are, however, some Amœbæ which can only emit pseudopodia from a special region, and which therefore possess *permanent* progressing and following regions.

It appears probable that a delicate film of firmer nature rapidly forms on the surface of naked protoplasm. The direction of pseudopodia may perhaps be determined by the rupture of such a film at definite points.

5. Irritability and Spontaneity.—That Amœba is affected by external stimuli may readily be noticed. Pseudopodia which come in contact with food-particles flow around them, but inedible substances are rejected. Increase of temperature enhances activity, but as 35° C. is neared, this is diminished, and arrested when that point is reached. Death is caused by a rise of 5° or 10° more. On the other hand, activity is diminished by cooling, and arrested at the freezing-point. Weak electric shocks cause the animal to assume the spherical form, and become quiescent.

As Amœba is constantly moving, and as its movements are to a certain extent purposeful, it cannot be doubted that some of them are *spontaneous—i.e.*, not directly due to external stimuli.

§ 2. VORTICELLA (Bell Animalcule).

Vorticella is microscopic, but as numbers usually occur together, attached to marine and fresh-water plants, &c., whitish fluffy patches are formed, readily distinguishable without the aid of a lens.

MORPHOLOGY.

1. External Characters (Fig. 91).—The body, as the name implies, is bell-shaped, and it is attached to some object, in most individuals, by an elongated slender stalk. The animal possesses considerable powers of movement, and is usually found either expanded or retracted. In the former condition the stalk is straight, or slightly curved, and the thickened edge or *peristome* (*w*) of the bell is *everted*—*i.e.*, turned outwards. The body-substance projects from the space within the peristome, and its rounded surface is termed the *disc.* The plane of this makes a slight angle with the plane of the bell-mouth, sloping down at one side to become continuous with the peristome, whilst on the other side there is a depression, the *vestibule.* Around the peristome and disc is a fringe of *cilia*—delicate, hair-like, protoplasmic processes, arranged in a very short spiral. The retracted state

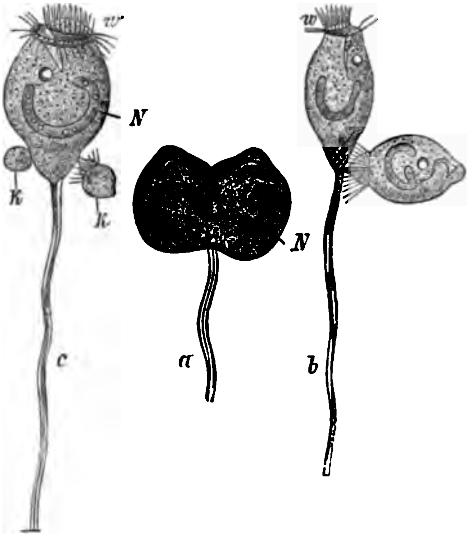


Fig. 91.—VORTICELLA (from *Claus*, after *Stein*) (enlarged).—*a* and *b*, Stages in transverse fission. N, Elongating nucleus; *c*, conjugation of small individuals, *k*, *k*, with fixed form, *w*, peristome, to left of which is vestibule. N, Nucleus, above which is small spherical contractile vacuole.

is produced by the withdrawal of the disc, the folding-in of the peristome, so that the body becomes rounded, and the shortening of the stalk, which is thrown into a spiral.

Smaller free-swimming, stalkless individuals are also met with, similar in structure to the others, but possessing a circlet of cilia near the stalk-end of the body.

2. Structure.—The body is transparent as in Amœba, and its internal parts can therefore be readily studied. Covering the whole external surface, cilia excepted, is a thin elastic membrane, the *cuticle*, which, *under very high powers of the microscope*, appears dotted. It is thinnest on the disc and peristome, and thickest on the stalk, of which it forms the sheath. The protoplasm is divided into a firm, finely granular, external *ectosarc* or *cortical layer*, and a semi-fluid *endosarc*. The ectosarc exhibits more or less distinct superficial transverse, and deeper longitudinal *myophan striations*. This deeper part is produced into a contractile filament, which is slightly twisted in a spiral manner, and traverses the cavity of the hollow stalk, attached to the firm sheath. The cuticle is formed by the ectosarc, and is perforated by the cilia, which are continuous with this layer.

As in Amœba, a *nucleus* (N) and *contractile vacuole* (Fig. 90, F, *c.v*), are present. The former is a horse-shoe-shaped band placed in the broad end of the body, just within the ectosarc; the latter is spherical, and situated near the vestibule.

A rudimentary **digestive apparatus** can here be distinguished for the first time. The vestibule, which performs the function of a *mouth*, is continued into a short tube, the *pharynx*, which is lined by a continuation of the cuticle, and is provided with numerous short cilia. It passes down into the body with a somewhat curved course, and ends abruptly within the endosarc. A small area in the vestibule, beneath the disc, is devoid of cuticle, and serving, as it does, for the extrusion of indigestible remnants of the food, may be termed the *anus*. Within the endosarc numerous *food-vacuoles* may usually be distinguished.

PHYSIOLOGY.

1. Nutrition.—The combined action of the cilia produces a kind of vortex, into which minute organisms and organic particles are drawn. These pass down to the end of the pharynx, and, together with a small amount of water, are forced into the endosarc by contractions of the body. There, as *food-vacuoles*, they slowly pass down one side of the body and up the other, the water being gradually absorbed, and the nutritious parts digested as in Amœba. The undigested remnants are ejected from the anus, which is only visible at that time, and carried off by a ciliary counter-current setting out of the vestibule.

Under unfavourable conditions Vorticella sometimes detaches itself from its stalk, and swims away by means of its cilia, becoming re-attached, and developing a new stalk, if a suitable spot is reached. As in Amœba, unfavourable conditions may also lead to *encystment*, the body, either whilst attached to its stalk or after separation, becoming rounded, and secreting a protective horny cyst.

One species of Vorticella, *V. viridis*, possesses *chlorophyll* diffused throughout its body, which no doubt enables it to live, in part, like a green plant.

2. **Destructive Metabolism.**—As in Amœba, something akin to a *digestive secretion* is probably formed by the protoplasm. The same waste-products, namely, carbon dioxide, water, and ammonia compounds, result from the breaking-down of the body, and, as before, the *contractile vacuole* is doubtless **excretory** and **respiratory**, pumping waste-products into, and oxygenated water out of, the vestibule, with which it has been observed to communicate.

3. **Reproduction** (Fig. 91).—This is *asexual*, and usually takes place by *binary fission* (*a* and *b*) in a longitudinal direction. The animal broadens, a furrow appears, and the bell is gradually cleft down to the stalk, the nucleus and contractile vacuole being halved. The stalk itself is then divided, and two equal-sized individuals result. As this process only requires an hour or two for its completion, the occurrence of Vorticellæ in groups is not to be wondered at.

Sometimes fission leads to the formation of two individuals of *unequal* size (*b*), the larger of which remains attached to the stalk, while the other develops a circlet of cilia at its *posterior* (*i.e.*, stalk) end, and is liberated as a free-swimming bell, which can fix itself and develop a stalk, the posterior cilia being lost. An individual may also divide into a number of small free-swimming bells, formed simultaneously.

An important process, known as **conjugation** (*c*), which has an important bearing on reproduction, also frequently occurs. A small free-swimming bell comes into contact, by its posterior end, with a large fixed bell at a point near the junction of the stalk. The two gradually fuse together, the nuclei uniting. Increased vigour appears to be imparted by this process, which generally shows itself in increased reproductive energy, as shown in fission. More rarely, encystment may follow, when the nucleus becomes larger and much longer, ultimately breaking up into a number of *spores*, oval bodies provided with a circlet of cilia at one end. These are liberated by the rupture of the cyst, and becoming attached by their ciliated ends, grow up into adult forms. Before this they may, however, increase by a process of fission.

4. **Contractility.**—The presence of a firm cuticle prevents the formation of pseudopodia, though protoplasmic flowings are observable in the endosarc, by which the food-vacuoles are carried round the body, and to a much less extent in the firmer ectosarc. Locomotion is effected in the free forms by cilia, which also produce the currents that bring food and carry away waste. Each cilium is a delicate thread of protoplasm, protruded from the ectosarc through a pore in the cuticle. By means of the alternate contraction of its longitudinal halves, bending and straightening are produced in turn.

The retraction of the body is due to the ectosarc, and in this case contraction takes place in the direction of the longitudinal myophan striation, whence it appears that the deeper layer is the part mostly concerned in the process. The spiral direction taken by the contractile thread in the stalk causes this to be readily thrown into spiral folds. The much slower process of expansion appears to be largely due to the elasticity of the cuticle, and this is especially true of the stalk. Re-opening of the bell is probably partly effected by the contraction of the superficial, transversely-striated part of the ectosarc.

5. **Irritability and Spontaneity.**—These phenomena are much more definitely exhibited than is the case in Amœba. The animals appear sensitive to the slightest touch, which causes them to contract rapidly. The same effect may be produced by irritant solutions, such as weak acetic acid, and by other stimuli. **Spontaneity** is shown by the way in which the cilia work together to a common end, instead of acting irregularly. They also cease acting at the same time. The purpose displayed by free-swimming bells, both in fixing and conjugation, is a good example of the same thing.

CHAPTER II.—CŒLENTERATA.

§ 3. HYDRA (Fresh-water Polype).

A small animal common in ponds, ditches, and stagnant streams. Extended specimens measure from half an inch in length downwards. There are two common kinds, the Brown Hydra (*Hydra fusca*), and the rather smaller Green Hydra (*Hydra viridis*).

MORPHOLOGY.

1. **External Features** (Fig. 92).—The extended body (A) is cylindrical in shape, and is usually attached to some object by a suctorial disc, the "*foot*" (*f*) situated at one end. The other is terminated by a conical projection, the *hypostome*, in the centre of which is a rounded opening, the so-called "*mouth*" (*m*). From the base of the hypostome, five to eight thin processes of the body, *tentacles* (*tn*), grow out. These are placed at regular intervals. This end of the body is termed *oral*, the other end *aboral*. Both body and tentacles may undergo various stages of contraction or shortening. In extreme contraction, the entire animal appears (A′) like a small, rounded, gelatinous knob, brown or green, according to the species. The external appearance presents certain characteristic features in connection with reproduction (*see below*).

By looking down upon the oral end of Hydra, it is seen that a number of lines can be drawn radiating from the centre of the mouth along the tentacles, all of which pass through similar parts. This kind of regularity is called *radial symmetry*.

2. **Body-wall.**—Amœba and Vorticella are *unicellular*, each being made up of one *cell* or *morphological unit*. These animals therefore possess diverse parts in virtue of the specialization, *differentiation*, of the protoplasm of single cells. Hydra, on the other hand, is *multicellular*, being made up of very numerous cells, each of which is morphologically equivalent to an Amœba. These cells, however, are modified in various ways (just as the *parts* of a *single cell* may be modified) for the performance of

diverse functions. This is the principle of **physiological division of labour**, and the accompanying diversity of form is termed **morphological differentiation.** Both of these principles have been exemplified already in the case of plants. Aggregations of cells, similar in form and mode of origin, and specially capable of carrying on a particular function (instead of *all* functions, as in Amœba), are known as **tissues**, and these again are interwoven into **organs**, digestive, reproductive, &c. In Hydra this is seen only in a rudimentary form; but, as the animal scale is ascended, physiological division of labour and morphological differentiation become more and more marked.

Histology.—The body and tentacles of Hydra contain a continuous cavity, the wall of which is, of course, the *body-wall.* The cells composing this are divided into two distinct layers, an external *ectoderm* (*ec*), and an internal *endoderm* (*en*), about twice as thick. Between the two is a very thin structureless membrane, the *intermediate* or *supporting lamella* (*i.l*), not composed of cells.

The **ectoderm** (*ec*) is mainly made up of large *tailed-cells* (C). These consist of a somewhat conical portion, broadest externally, tapering internally, and ultimately produced into one or more processes or tails, which may branch, and appear to be closely connected with the supporting lamella. They are arranged longitudinally. The conical parts, each of which has a clearer striated border, and possesses a large nucleus with nucleolus, are united together externally, whilst, internally, spaces are left between them which are occupied by *interstitial cells* (*i.c*). These are small nucleated cells often crowded together, so as to obscure their individual outlines. Some of them become converted into *thread-cells* (D), which gradually force their way to the surface between the tailed-cells, and are, therefore, as it were, embedded in them. They are most abundant in the tentacles, where they are aggregated into "batteries," giving rise to an irregular surface. Several kinds may be distinguished. The most perfect consist of a transparent vesicle containing fluid, and surrounded by a thin layer of protoplasm. This layer is produced externally into a stiff *trigger-hair*, which slopes towards the free end of the body, or tentacle, as the case may be, while at the base of the vesicle it contains a nucleus. It is the remains of the original interstitial cell, from which the thread-cell has originated. The vesicle has a long tapering neck, which towards its end bears several large barbs directed backwards and numerous minute barblets, and passes into an extremely long and delicate hollow filament or thread. In the quiescent state, the neck is folded into and the

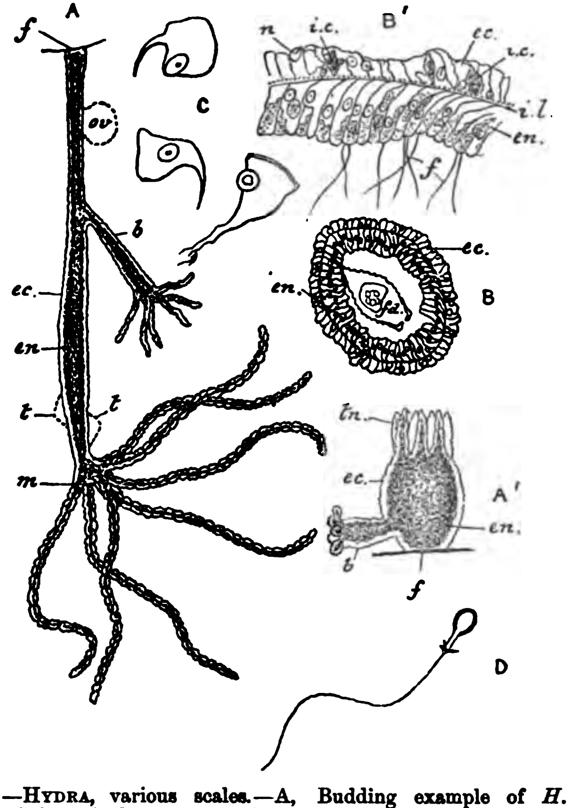


Fig. 92.—Hydra, various scales.—A, Budding example of *H. fusca* extended; A′, ditto, retracted; B, transverse section of *H. fusca*; B′, part of same, on larger scale; C, isolated tailed-cells; D, isolated thread-cell, from *H. viridis*; *f*, foot; *m*, "mouth;" *tn*, tentacles; *ec*, ectoderm; *en*, endoderm; *b*, bud; *ov*, typical position, &c., of ovary; *t*, do., of testes; *i.l*, intermediate lamella, the dots above this represent the cut ends of "tails;" *i.c*, interstitial cells; *n*, thread-cells; *f*, flagella; *fd*, organism (in B) in digestive cavity, as food.

filament coiled up within, the vesicle. There are also other much smaller thread-cells with shorter and thicker threads devoid of barbs. Small star-shaped *nerve-cells*, connected with the protoplasmic investment of the thread-cells, are said to exist.

The **endoderm** (*en*) is made up of a single layer of large, granular, irregular cells, containing a big flattened nucleus with nucleolus, and one or more vacuoles, often of great size. The endoderm cells abut at one end upon the supporting lamella (and have been stated to be here produced into *transversely*-arranged tails), while the other end projects into the cavity of the body, and can be produced into pseudopodia. This end often bears one or more elongated flagella (*f*). The external half of each cell contains in *Hydra viridis*, numerous small globular bodies, coated with chlorophyll. *Hydra fusca* possesses small bodies of similar nature, which contain sooty particles.

3. Digestive Organs.—The "*mouth*," or *blastopore* (*m*), leads into a large digestive cavity, the *archenteron*, which is produced into the tentacles. It is lined throughout by endoderm.

4. Reproductive Organs.—Male and female sex-organs are differentiated, and, as both occur in the same animal, Hydra is said to be *hermaphrodite*. They are found, as a rule, only in the summer months.

(1.) **The Male Organs** consist of a varying number (1 to 20) of *testes* (*t*, *t*), typically placed near the oral end of the body. Each is a conical or rounded elevation, the *wall* of which is formed by tailed cells, while within is an aggregate of interstitial cells. The testes are, in fact, projections caused by the increase of these cells at particular points of the body. These contained *germinal cells* develop into *spermatozoa*, minute, tadpole-like bodies, with oval heads and long vibratile tails. The head of the spermatozoon is mainly formed from the nucleus of the germinal cell, covered by a thin film of its protoplasm, the rest of which is drawn out into the tail.

(2.) **The Female Organs** are known as *ovaries* (*ov*), and are typically developed at the aboral end in the same manner as the testes. *Hydra viridis* usually has but one ovary; *H. fusca* may possess from one to eight. Each is a rounded projection, much larger than a testis, and, when mature, contains a single large egg-cell or *ovum*. The young ovary contains at first a large number of germinal cells. One of these, occupying a central position, grows more vigorously than the others, becomes amœboid, and uses them as food, amœba-fashion. This is the ovum. It assumes a spherical form on attaining its full size, and though resembling ordinary cells in structure, its parts receive special names. The protoplasm is termed *vitellus.* This contains numerous highly refractive bodies, known as *yolk-spherules.* The large spherical nucleus, or *germinal vesicle,* contains a nucleolus, the *germinal spot.*

PHYSIOLOGY.

1. **Nutrition.**—The food consists of small animals, often of relatively high organization. The tentacles are the agents by which these are conveyed to the mouth, and their thread-cells play an important part in this connection. The following explanation applies to the large forms. In the quiescent state, the neck and filament of the thread-cell are *inside* the vesicle, which contains a poisonous fluid. If now a small animal touches the trigger-hair, the neck is first turned inside out, *everted* (*d*), and, by means of its barbs, fixes itself in the animal. The thread is now everted within the wound, and the poisonous fluid covering its exterior exerts a paralyzing influence. The mouth is very elastic, and capable of taking in morsels of considerable size (B *fd*). Within the digestive cavity movement of fluids, &c., is mainly effected by the action of the endodermic flagella. The endoderm-cells vary much in size at different times, and can extend themselves so as to almost obliterate the cavity. The food is no doubt acted upon to some extent by a fluid secretion poured out of these lining cells, but digestion is also largely *intracellular,* the pseudopodia thrown out ingesting solid food-particles in the same way as in Amœba. Within these cells the food is reduced to solution, or fine division, and readily passes to the other parts of the body, mainly by diffusion. Undigested remnants are passed out through the mouth.

In *Hydra viridis* the presence of chlorophyll enables the nutrition to be partly effected as in green plants.

2. **Destructive Metabolism.**—The endoderm-cells appear to secrete a digestive fluid, and the thread-cells a poisonous one, while all parts of the body alike give rise to waste-products.

Very possibly the *ectoderm* is more especially **respiratory** (excreting carbon dioxide and taking in oxygen), on account of its proximity to the surrounding water, which must be better oxygenated than the fluid in the digestive cavity, although the latter is frequently renewed. On the other hand, it is not improbable that the nitrogenous waste is mainly excreted into the digestive cavity by the endoderm. Such a division of labour in Hydra is, however, conjectural; and, if it exists, ill-defined.

3. Reproduction.—This is of two kinds, asexual and sexual, the one irrespective of, the other dependent on, the reproductive organs.

(1.) **Asexual Reproduction** (A and A′) is effected by *gemmation*, and is not dependent on the time of year. Out of the body grows a small knob, which both layers help to form, and which contains a cavity continuous with the archenteron of the parent. This bud (*b*) lengthens, develops a mouth and tentacles, and finally becomes pinched off at its aboral end, which forms a foot for itself. Several buds in the same or different stages of development may be present in an individual at the same time, and, under favourable circumstances, these may themselves bear buds before becoming detached. *Fission* does not occur in nature, but a Hydra may be cut into several pieces, each of which can develop into a new and perfect individual.

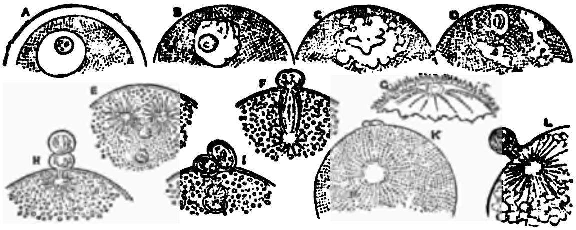


Fig. 93.—FORMATION OF POLAR CELLS (from *Haddon*).—A, Ripe ovum with excentric germinal vesicle and spot. B-E, Metamorphosis of vesicle and spot into nuclear spindle. F and L, Expulsion of first polar cell. G, the same on the surface of the egg. H, Formation of second polar cell. I and K, the two polar cells on the surface of the egg.

(2.) **Sexual Reproduction.**—The wall of the ripe ovary bursts, and part of the surface of the now spherical ovum is exposed. By the rupture of the testis at its apex, the spermatozoa are liberated, and by the action of their tails move rapidly head first through the water. *Impregnation* or *fertilization* of the ovum now occurs (which is quite similar to the corresponding process in plants, *see p.* 34, for example), that is, a *spermatozoon* (derived from the same or a different individual) fuses with it (Fig. 94). This union of a small active male cell with a relatively large and passive female one, is the essential part of sexual reproduction. Before fertilization (Fig. 94), the germinal vesicle ejects parts of its substance from the ovum as *polar cells* (these correspond to the ventral-canal-cells in the Moss and Fern), and its remains are known as the *female pronucleus*. The entering spermatozoon loses its tail, and its head as the *male pronucleus* fuses with the female pronucleus to form the *segmentation-nucleus* of the fertilized ovum.

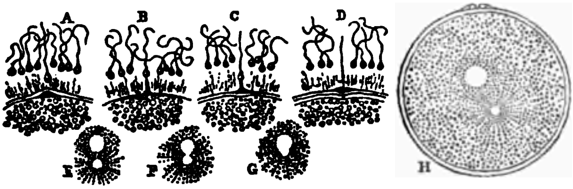


Fig. 94.—Fertilization of Ovum (from *Haddon*).—A-D, Stages in entry of a spermatozoon. H and E-G, Stages in fusion of male and female pronuclei. In H the polar-cells are seen on the surface of the egg.

4. **Contractility.**—Amœboid and ciliary movements are seen in the endoderm. Besides these, Hydra is capable of movements on a larger scale. The body and tentacles can either be extended or contracted, their appearance varying very much in consequence, and curvings, very complex in the case of the tentacles, can also be effected. These movements may lead to *locomotion*, either slow by the gradual shifting of the foot, or more rapid by the alternate attachment, sucker-like, of it and the mouth. The animal can also float passively near the surface of the water, mouth downwards, the foot assuming a concave form, and acting as a buoy.

The retraction of the body subserves *protection*, whilst the tentacular movements are mainly concerned with the procuring of food. All these movements are the result of longitudinal and transverse contractions, separate or variously combined. The tails of the tailed-cells are arranged longitudinally, and by their shortening or contraction furnish the retracting element. If the endoderm-cells really possess transversely-arranged tails, their contraction would give the necessary extending element. If this is not the case, the conical parts of the tailed-cells could effect the same purpose by contracting transversely, the result being a corresponding increase in length.

The eversion of the thread-cells is caused by the contraction of the protoplasmic investment of the vesicle. By this means the contained fluid is put under pressure, and everts first the neck, and then the hollow filament. There is no contrivance for effecting the reverse process, and thread-cells, when once used, are therefore discarded.

5. Irritability and Spontaneity.—Hydra is even more sensitive than Vorticella to external stimuli, and this is especially well seen in the movements of retraction and in the thread-cells. The trigger-hairs are **sensory**, that is to say, specially modified for the perception of external stimuli, in this case chemical. They are turned in those directions whence food is most likely to approach, *i.e.*, the oral end of body and tips of tentacles. The external surfaces of the tailed-cells appear to receive those stimuli which lead to movements.

Spontaneity is best shown by the co-ordination of cells to perform useful movements, such as those of locomotion, where external influences are acting only indirectly. The co-ordinative power certainly resides in the ectoderm, either in the tailed or nerve-cells, or probably in both. The eversion of the thread-cells also seems to depend on the "will" of the animal. If a trigger-hair is touched, an impulse of some sort appears to be transmitted to the connected nerve-cell, which, in the case of food, sends back an impulse leading to the eversion of the cell, while a particle of mud, say, causes no such disturbance.

DEVELOPMENT.

1. Early Stages.—After impregnation, the fertilized ovum undergoes the process of *segmentation*, that is, it divides into 2, 4, 8, 16, &c., until an aggregate of small cells is formed, each possessing part of the original vitellus and segmentation-nucleus. The segmentation is *complete* and *regular*, all the ovum undergoing division, which proceeds regularly by continuous bipartition. The mass of cells formed by segmentation is solid, and is termed a *morula*. The outer cells become transformed into a firm horny coating, produced externally into spines and ridges. Within this a more delicate membrane is secreted. These changes occupy about four days, and, after their completion, the embryo falls from the ovary into the mud, where its development is slowly finished during the winter months.

2. **General Growth.**—The cells of the embryo fuse into a continuous mass, in the centre of which the *archenteron* appears. This gradually becomes larger. Two cell-layers, the **epiblast** and **hypoblast**, are formed by a process of splitting or *delamination*. The outer part of the fused mass becomes clearer than the rest, and in it first the tailed-cells, and then the interstitial cells, appear. The cells of the hypoblast are differentiated later. The epiblast and hypoblast correspond to the ectoderm and endoderm of the adult. Owing to the increase in size of the embryo, the outer coat is ruptured, and the inner membrane is subsequently thrown off. The blastopore is formed by absorption at one end, and around this the tentacles grow out. These do not all appear at the same time, but are formed in pairs.

CHAPTER III.—VERMES.

§ 4. DISTOMA (The Fluke).

The best-known kind of fluke is *Distoma hepatica*, the Liver Fluke. This is a small parasite, when adult about an inch and a half long, which lives in the bile-ducts of several animals, more especially the sheep, and causes the disease known as liver-rot.

MORPHOLOGY.

1. **External Characters.**—The animal (Fig. 96) exhibits *bilateral symmetry*, right and left halves being distinguishable, each of which is, so to speak, the reflection of the other. This figure of speech is grounded on the fact that if either half be removed and placed with the cut edge against a looking-glass, its reflection will exactly resemble the other half.

The body is very much flattened, broad upper and lower, or *dorsal* and *ventral* surfaces being distinguishable, which pass into sharp edges at the sides and behind. The shape is somewhat oval, but at the *anterior* (*i.e.*, front) end the gently curved outline is interrupted by the *head-papilla*, a projection much narrower than the rest of the body. This tapers to a blunt point, and ends in a rounded adhesive surface, the *anterior sucker*, which looks somewhat ventralwards. Behind the head-papilla the sides of the body curve outwards and backwards till the maximum breadth is attained at about the junction of the anterior and middle thirds. They then slope backwards and inwards to the *posterior* (*i.e.*, hind) end of the body. There is a *ventral sucker* (*v.s*) on the ventral surface, a little way behind the head-papilla.

Four unpaired median apertures are present on the surface of the body. These are:—(1) The *mouth* (*m*), in the centre of the anterior sucker; (2) the minute *excretory pore* (*ex.p*) at the posterior end; (3) the *genital aperture* (*g.o*) on the ventral surface between the suckers; and (4) the extremely minute opening of *Laurer's canal* on the dorsal surface.

With the exception of the smooth suckers the body surface is rough, owing to the presence of immensely numerous minute *spines*, which are directed backwards.

2. **Skin.**—This is the name given to the external layer of the body. It is made up of an *epidermis*, composed of a single layer of large granular nucleated cells aggregated together into a membrane, and a *cuticle*. This is a horny layer, similar to the cuticle of Vorticella, not itself composed of cells, but formed by the epidermic cells on their outer surface. It is traversed by numerous delicate canals which run in a slanting direction from its outer

to its inner surface, and are produced externally into the small spines mentioned above. Since the cuticle subserves a supporting function, it may be regarded as a *skeleton*, which, being external, is an *exoskeleton*. Like other structures of this kind it is also a means of protection.

3. Digestive Organs (Fig. 95).—The *mouth* (O) is an oval opening placed within the anterior sucker, and leading into a small *mouth-cavity*. This is followed by the oval, thick-walled *pharynx*, the anterior end of which, except during feeding, projects into the mouth-cavity and almost fills it up. A very short, straight and delicate tube, the *gullet* or *œsophagus*, comes next, which opens into a bifurcated *intestine*. Each half of this is a wide, thin-walled tube (D), running back to the end of the body, and situated near the middle line. A number of small pouches project from its inner side, whilst a large number of pouches, mostly considerably branched, extend from its outer side to the edge of the body.

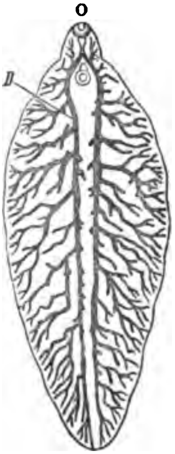
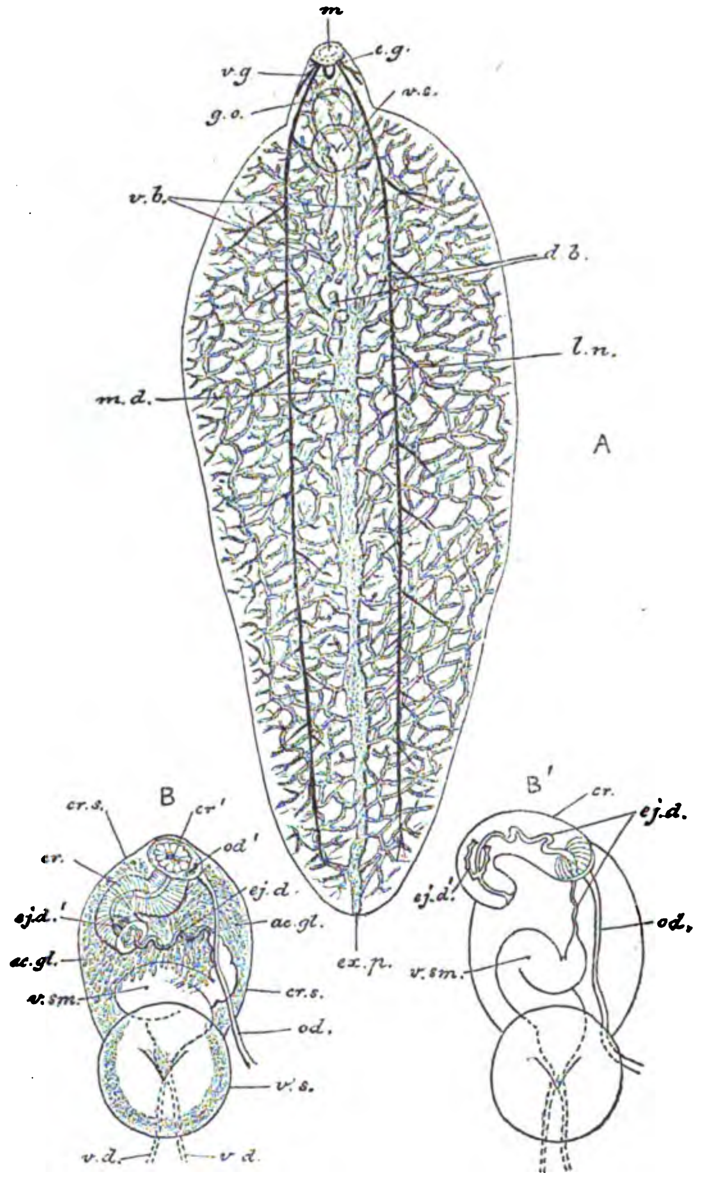


Fig. 95.—Distoma (from *Claus* after *Leuckart*) — Alimentary canal. O, Mouth, a short distance behind which is ventral sucker. D, right limb of intestine.

Special *muscles—i.e.*, bands of contractile fibres—are connected with the pharynx. A sheath of such fibres, the *protractor muscle*, closely surrounds this organ, and, on the other hand, is connected with the anterior sucker, while *retractor muscles*, in the form of contractile bands, slant back from the pharynx to the dorsal wall of the body.

Histology.—The pharynx is lined by a continuation of the general cuticle. Its wall is very muscular, the fibres taking various directions. The gullet and intestine have very thin walls, which are formed by a structureless membrane externally, and a lining of *epithelium* internally. This name is applied to membranes, formed by one or more layers of cells, which cover external and line internal surfaces. The epithelium in question is *simple*—only one cell thick—and *columnar*, the constituent cells being longer than broad. Each possesses a large granular nucleus, and is capable of sending out pseudopodia into the digestive cavity.


m
c.g.
v.g
v.c.
g.o.
v.b.
d.b.
l.n.
m.d.
A
ex.p.
B
cr.s.
cr′
cr.
od′
ej.d.
ej.d.′
ac.gl.
ac.gl.
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cr.s.
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B′
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Fig. 96.—Excretory, Nervous, and Reproductive Organs of Distoma Hepatica. Enlarged (after *Sommer*).—A, Excretory and nervous system; *m*, mouth; *v.s*, ventral sucker; *g.o*, genital opening; *v.b* and *d.b*, chief ventral and dorsal branches of excretory duct (one of the latter only partly drawn); *m.d*, main duct; *ex.p*, excretory pore; *c.g*, cerebral ganglion; *v.g*, ventral ganglion; *l.n*, lateral nerves. B and B′, Reproductive organs contained in cirrus-sac, *cr.s*. In B′ the cirrus is partly everted. *v.s*, Ventral sucker; *od*, oviduct; *od′*, opening of ditto; *v.d*, vasa deferentia; *v.sm*, vesicula seminalis; *ej.d*, ejaculatory duct; *ej.d′*, aperture of same on papilla; *cr*, cirrus; *cr′*, opening of ditto; *ac.gl*, accessory gland (not shown in B′).

The digestive and other organs are imbedded in a mass of tissue, *connective-tissue*, which extends throughout the body. It subserves support and connects the various parts together, hence its name. Polyhedral nucleated cells are the main constituent of this tissue in the Liver Fluke, but there is also a certain amount of non-cellular fibrous material between these. The outer layer of the gullet and intestine is also of this nature.

4. Excretory Organs (Fig. 96, A).—Those organs are termed "excretory," the function of which is to get rid of nitrogenous waste, together with a considerable amount of water. They here form a network of tubules ramifying throughout the body. The smallest tubes open by ciliated funnel-shaped ends into the minute spaces, *lacunæ*, everywhere present in the tissues, and collectively representing the continuous space, or *body-cavity*, found outside the organs of most animals. These small tubes branch copiously, and are united into a network. They open into larger tubes, which, in the anterior quarter of the body, are continuous with four still larger longitudinal trunks, two dorsal (*d.b*) and two ventral (*v.b*), and in the posterior three-quarters with a median longitudinal trunk, formed by the union of the four trunks aforesaid. This *main duct* (*m.d*), the largest excretory trunk, runs back, just beneath the dorsal wall of the body, to open by the minute *excretory pore* (*ex.p*).

Histology.—The delicate walls of the excretory tubes are made up of a single elastic and structureless layer. They contain a clear fluid, in which are numerous highly refracting granules.

5. Reproductive Organs (Fig. 97).—Distoma is hermaphrodite, and its very complex reproductive organs lie, for the most part, ventral to the intestine. The *genital aperture* (Fig. 96, *g.o*) is a small oval, or chink-like orifice, situated in the middle line between the anterior and ventral suckers, rather nearer the latter. It leads into a shallow pit, the *genital sinus* (Fig. 96, B), on the right of which is the larger *male aperture* (*cr′*), and on the left the *female aperture* (*od′*).

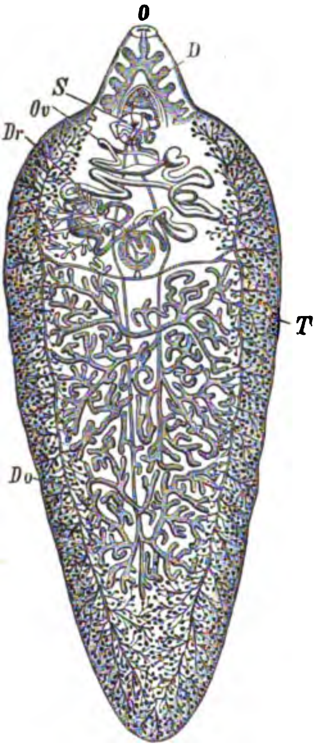

Fig. 97. — Distoma Hepatica (from *Claus* after *Sommer*).—O, Mouth; D, limb of intestine; S, ventral sucker, in front of which is genital opening; T, testis, in front of which is the rounded shell-gland; Do, yolk-gland; Ov, oviduct; Dr, ovary.

(1.) **The Male Organs** consist of two *male gonads* or *testes* (T), one behind the other, extending over a considerable area in the middle region of the body. Each is made up of several much-branched tubes, which unite together to form a tube or duct of smaller calibre, the *male gonaduct* or *vas deferens.* The *vasa deferentia* run forwards, on either side of the middle line, to the level of the ventral sucker (S). In the latter part of their course they converge (Fig. 96, B, B′), and at the above level open into a spindle-shaped thick-walled tube, the *vesicula seminalis* (*v.sm*). This is somewhat bent back upon itself. It extends rather further forwards than the sucker, and tapers into a very delicate convoluted tube, the *ejaculatory duct* (*ej.d*), which again opens into a shorter and stouter tube, the *cirrus* (*cr*), which opens at the male aperture. Around the end of the ejaculatory duct a mass of nucleated cells is arranged, each of which opens by an excessively fine tube into the duct. They are the *accessory glands* (*ac.gl*).

A *gland* is an organ essentially composed of one or more epithelial-cells, in which some special secretion or excretion is formed. The simple *unicellular*, *i.e.*, one-celled, condition is seen in the accessory glands.

The vesicula seminalis, ejaculatory duct, accessory glands, and cirrus are contained in the *cirrus-sac* (*cr.s*), a hollow oval body with muscular walls, lying between the ventral sucker and genital opening.

(2.) **The Female Organs** are made up of the following parts:—The unpaired *female gonad* or *ovary* (Dr) is usually placed on the right side, in front of the anterior testis. It is composed of several branched tubes, which unite together to form the *female gonaduct* or *oviduct* (Ov). This is first very narrow, then gradually enlarges and becomes considerably convoluted, and finally narrowing, opens by the female aperture (Fig. 96, B, *od'*). The dilated part of the oviduct is termed the *uterus*. Two important glands are connected with the female organs. (1.) The *yolk-glands* (Do) are paired bodies, each of which is made up of an immense number of minute rounded structures, *acini*, and extends over a lateral strip outside the other reproductive organs. . Behind the testes the two meet in the middle line. From the acini fine ducts proceed, which unite into large ones. These finally open into a longitudinal duct which runs along the inside of the gland. Just in front of the anterior testis a transverse duct arises from this trunk, which unites with its fellow in the middle line to form a small *yolk-reservoir*, from which the short unpaired *yolk-duct* runs forwards to join the oviduct not far from its commencement. Just before their union a fine tube, the *canal of Laurer*, passes from the yolk-duct to the dorsal surface, where it opens by a minute aperture. (2.) The numerous *shell-glands* are similar to the accessory glands. They are aggregated into a rounded mass, and open into the oviduct near its junction with the yolk-duct. (*See Fig.* 97, *just below convoluted oviduct*).

Histology.—The tubules of the testis are supported by a structureless wall, on the outside of which filamentous contractile cells are arranged longitudinally. There appears to be a lining of germinal epithelial cells, *spermatospores*, some of which become free, and give rise to tufts of spermatozoa. Only part of the substance of the spermatospores is used up in this process. Each spermatozoon possesses a small oval *head*, and long vibratile *tail.* The walls of the vesicula seminalis, cirrus-sac, and cirrus contain muscle-fibres variously arranged, and the last is lined by a continuation of the spiny cuticle covering the body.

The *ovarian tubules* possess supporting layers, and are lined by germinal epithelium, the cells of which become *ova.* Each of these has a small vitellus, and large germinal vesicle, with germinal spot. In the acini of the *yolk-glands* a formation of *yolk-cells* occurs. These contain a large amount of nutritious matter. Yellowish drops of fluid are formed by the *shell glands,* which can harden into shell substance.

6. **Muscular System.**—This carries on more particularly the contractile function. In addition to the muscles already mentioned in the description of the various internal organs, those effecting the general movements of the body must be noticed. These movements are mainly due to the *dermal musculature,* a sheet of muscle intimately connected with the skin, and together with it making up the body-wall. This sheet is composed of three layers, external, middle, and internal, the fibres of which take respectively transverse (circular), longitudinal, and oblique directions.

The suckers are very muscular, and the arrangement of their muscles is rather complex.

Running through the connective-tissue, which fills up the space between the organs, are a great many muscular bands. These take a dorso-ventral direction, and are also connected together so as to form a close network.

Histology.—The muscles are made up of non-nucleated contractile fibres resulting from the metamorphosis of cells.

7. **Nervous System** (Fig. 97).—Under this term are included those organs which have more especially to do with irritability and spontaneity.

Around the pharynx is placed a *nerve-ring,* the plane of which slopes downwards and backwards. In its dorsal part there is a swelling, the *cerebral ganglion* (*c.g*), on either side, and a similar unpaired *ventral ganglion* (*v.g*) below. From each cerebral ganglion two small filaments, *nerves,* are given off to the head-papilla, in which they branch, whilst a stouter *lateral nerve* (*l.n*) runs back almost to the end of the body, giving off branches as it does so. It lies just within the ventral body-wall, below the reproductive organs, and is separated from its fellow by about one-third the breadth of the body. Excessively fine filaments are given off from the ventral ganglion to surrounding parts.

Histology.—Two elements make up the essential part of the nervous system—(*a*) *Ganglion-cells*, (*b*) *Nerve-fibres.* The ganglion-cells are found more particularly in the ganglia, but are also present in less abundance in parts of the nerve-ring. They are irregular in shape, with several projections or processes, and a very distinct refractive nucleus. The nerve-fibres are extremely delicate threads, formed by altered cells, which make up the nerves and most of the nerve-ring. They are continuous on the one hand with the processes of the ganglion-cells, on the other with the various organs of the body.

PHYSIOLOGY.

1. **Nutrition.**—The food consists of bile, together with blood and disintegrated liver-substance, resulting from the "rot." This is taken in by the action of the pharynx, which acts somewhat like a piston. By the retractor muscles it is drawn back, when the food rushes into and fills the mouth-cavity. The mouth is now closed and the pharynx brought forwards by the protractor muscle. As, meanwhile, its cavity is enlarged by the contraction of radial fibres in its wall, food passes in, and (the cavity being diminished by the contraction of other fibres), is squeezed on into the gullet and intestine. These present a large absorbent surface which can at once take in the fluid part of the food. The amœboid epithelial cells effect intracellular digestion to some extent, while they also appear to secrete a digestive fluid which can bring solid food into solution or a fine state of division. Undigested matter is ejected from the mouth. The digested material gradually diffuses through the intestinal wall to the other parts of the body.

2. **Destructive Metabolism.**—There are no special organs of **respiration**, and this function is doubtless effected by the general body-surface.

The **excretory organs** carry away nitrogenous waste. Guanin ($C_5H_5N_5O$) has been detected in them.

3. **Reproduction.**—Entirely **sexual.** It appears doubtful whether two individuals unite, or self-fertilization is effected.

The cirrus can be everted, and may perhaps function as a *copulatory organ*, conveying the male elements (*sperm*) into the female passages of another individual. In this case the end of the oviduct no doubt receives the cirrus in copulation, and must be termed the *vagina*. Self-fertilization (which is, however, exceptional in hermaphrodites) could be effected by a closure of the genital sinus, the sperm passing directly from the male to the female aperture. In any case the sperm is ejected by the contraction of the walls of the vasa deferentia and vesicula seminalis.

The ova are fertilized in the upper part of the oviduct, polar cells having probably been previously formed (*see Fig.* 93).

4. Contractility.—*Amœboid* movements may be seen in the intestinal epithelium, and *ciliary action* in the excretory funnels and spermatozoa.

For the production of more definite movements it is advantageous that the contractile elements should be elongated. This was seen in the tailed-cells of Hydra, and is still more distinctly exemplified here. All *muscular movements* are produced by the shortening of muscle-fibres, which become proportionately broadened. The two ends are thus brought nearer together, and the parts to which they are attached tend to approximate. In the case of fibres surrounding a cavity in a circular direction (pharynx, for example), narrowing of the cavity takes place, and the reverse is effected by longitudinal fibres.

Locomotion is caused by the dermal musculature in the following way:—The ventral sucker is fixed and the head-papilla elongated by the contraction of its circular muscle-layer. The anterior sucker then attaches itself, the ventral sucker being at the same time loosened, and the body is dragged forward by the contraction of its longitudinal muscle-layer.

A **muscle** is an aggregation of muscle-fibres possessing a definite form and function. The protractor and retractor muscles of the pharynx are examples. Very generally one end of a muscle is attached to a relatively fixed, the other to a relatively movable, point. These attachments are respectively the *origin* and *insertion*. Thus, the origin of the retractor muscles of the pharynx is in the dorsal body-wall, their insertion in the wall of the pharynx. Hence by their contraction the relatively movable pharynx is dragged back.

5. Irritability and Spontaneity.—The different functions are regulated and correlated by the nervous system. The nerve-fibres are, so to speak, telegraphic wires by which the different parts of the body are placed in intercommunication. They possess peripheral ends connected with the various organs, and central ends connected with the ganglion-cells, which are themselves linked together. These are, as it were, receiving and despatching offices. The nerve-fibres are doubtless here, as in higher forms, of two kinds—**afferent** and **efferent**—transmitting molecular impulses *to* and *from* the ganglion-cells respectively. The ganglia, as containing the majority of the ganglion-cells, may be called the *central organs.* A very large number of afferent nerve-fibres are *sensory*, stimulation of their peripheral ends by appropriate means leading to *sensations*, which, however, do not arise in the sensory fibres, but in the central organs, consequent on impulses conveyed by those fibres. How far the Fluke can be said to possess special sensations is doubtful. That of *touch* is probably present, its seat (a convenient but incorrect word, localizing sensations in the parts stimulated) being the skin, especially that of the head-papilla. The stimuli which can produce this sensation are pressure, heat, and cold. The last two terms are used for temperatures above or below that of the skin.

The two small nerves passing from either cerebral ganglion to the head-papilla are probably special nerves of touch.

Most *efferent* nerve-fibres are *motor*, that is, they convey impulses from the central organs to muscle-fibres (with which they are closely united), causing them to contract, and so to produce motion. Other efferent fibres regulate secretion, &c.

A considerable amount of **spontaneity** is evinced in the movements, &c., of the Fluke. Its seat is mainly in the cerebral ganglia, where also the "consciousness" of the animal probably resides, if it can be said to have any. Sensations are modifications of consciousness.

DEVELOPMENT (*Fig.* 98).

The Fluke is an *endoparasite*, living within and at the expense of another animal, its *host.* Like many other parasites, its life-history exhibits an **alternation of generations**, a phenomenon far less general in the case of animals than in the case of plants.

From the egg a young Fluke does not proceed direct, but a number of *asexual stages* intervene between it and the sexual form.

Segmentation occurs within the oviduct. It is regular and complete. The ovum, together with a number of yolk-cells, is enclosed in a horny shell to form the *egg*. This is oval in shape, with a smooth surface. The ovum lies at one end, and a small circular area of the transparent shell is here marked off as the lid or *operculum*. The further development occurs outside the body of the sheep, the eggs passing to the exterior with the excrement. It leads to the formation of a **free embryo** (*a* and *b*), which gradually comes to occupy most of the cavity of the egg, as the yolk-cells are used up. When fully developed, a sudden elongation of its body causes the operculum to fly open, and it is thus liberated. The body is somewhat conical, and the broad anterior end possesses a short retractile *head-papilla*. The external layer of the body-wall is formed by flattened *ectoderm-cells*, which, except on the head-papilla, bear long locomotive cilia. The deeper layer of the body-wall is granular, with rudimentary muscle-fibres, a pair of excretory funnels, and near the anterior end a pair of *eye-spots*. These are two small refracting cells, placed close together, and each containing a crescentic mass of pigment. The two crescents placed back to back present a somewhat X-shaped appearance. The interior of the body is mostly filled with rounded *germinal-cells*. If the free embryo finds itself in water or among damp herbage, it moves actively about by means of its cilia. If, within about eight hours, it meets with a small water-snail, *Limnaea truncatula*, development proceeds, but not otherwise. The head-papilla is lengthened, and the embryo, revolving rapidly, bores by its means into the snail. Within this host, generally in the lung-chamber, it becomes a **sporocyst** (*c*). The ciliated ectoderm-cells are lost, and the body gradually becomes an elongated and rather irregular sac. Its wall is covered externally with a cuticle, below which are feebly developed muscle-fibres, within which is a layer of epithelium lining the body-cavity. Several excretory funnels are present in the body-wall, and the eye-spots, separated from each other, can still be recognised. The sporocyst may increase by transverse fission, and it produces asexually within it a number of the next, or **redia** stage, in the following manner:—The body-cavity contains a large number of germinal cells, partly those of the free embryo, partly budded off from the lining epithelium, lying loosely within it. These become aggregated into small solid masses, *morulæ*, each of which becomes a *gastrula* (*i.e.*, a two-layered embryo with a mouth and rudimentary digestive cavity), by an inpushing or *invagination* of cells on one side. This becomes a redia, which bursts its way out of the sporocyst, the ruptured place afterwards closing up.

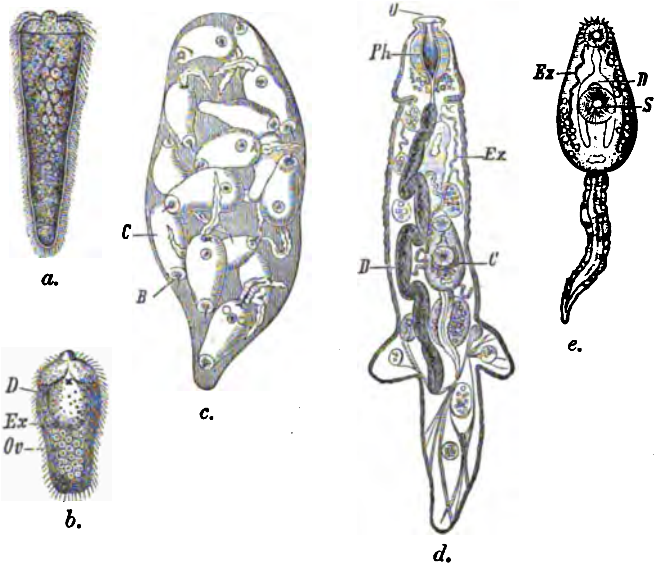

Fig. 98.—Development of Distoma (from *Claus*, partly after *Leuckart*). —*a*, Free swimming ciliated embryo: *b*, the same contracted, with rudimentary alimentary canal, D, germinal cells, Ov, and excretory organs, Ex: *c*, sporocyst full of cercariæ (this is not a sporocyst of *D. hepatica*, or it would be full of *rediæ*); B, boring papilla of cercaria: *d*, redia; O, mouth; Ph, pharynx; D, intestine; Ex, excretory organ; C, Contained cercariæ: *e*, free cercaria; S, ventral sucker; D, intestine; Ex, excretory organ; the little circles in the body represent cystogenous cells.

Redia (*d*).—Body elongated and cylindrical. Near the anterior end is an elevated ring or "collar," while not far from the posterior end a pair of blunt processes project, one on either side. The body-wall has a similar structure to that of the sporocyst, but the muscle is better developed. A *mouth* (O) is present at the anterior end of the body, which leads into a muscular *pharynx* (Ph). This is continued into a simple *digestive sac* (D). Branched *excretory trunks* (Ex) commencing in ciliated funnels are present.

The redia wanders over the body of the snail, the posterior processes acting as rudimentary feet, and feeds upon its tissues, especially the liver. The collar acts as a relatively fixed point upon which the anterior end can move when feeding. Within the body-cavity, *daughter-rediæ* (as many as ten), or (as many as twenty-three) the next, **cercaria** stage (*c*), may be developed, the former only in warm weather. In either case some of the epithelial cells lining the body-cavity enlarge and segment (*see oval and rounded masses in Fig.* 98, *d*) to produce morulæ, which become gastrulæ, and gradually assume the form of daughter-rediæ, or cercariæ. As a rule, both are not developed in the same redia. These escape by a special *birth-opening* behind the collar.

The **Free Cercaria** (*e*) resembles a minute tadpole. It has a rounded flattened body armed anteriorly with minute spines, and possessing anterior and ventral (S) suckers, and a muscular tail. The *body-wall* contains numerous large granular *cystogenous cells* (minute circles in fig.) A *mouth, pharynx, gullet,* and simple forked *intestine* (D) are present, as well as *excretory organs* (Ex). The cercaria makes its way out of the snail, loses its tail, and attaches itself to a grass-stem, the cystogenous cells pouring out a secretion which hardens into a bright white cyst. Cercariæ, thus encysted, are swallowed by sheep, the gastric juice dissolves the cyst, and the enclosed cercaria makes its way up the bile duct into the liver, there becoming, in about six weeks, a sexually mature Fluke. It is worthy of remark that the adult sexual stage lives in the higher vertebrate host, where it has a better chance of being preserved.

The following table summarizes the succession of stages :—

1. Sexual Fluke
(*in sheep, &c.*)

5. Cercaria
(*first free, then encysted on grass*).

2. Free Embryo.

4. Redia
(*in Limnaea truncatula, may produce daughter-rediæ*).

3. Sporocyst
(*in Limnaea truncatula, may produce fresh sporocysts by fission*).

§ 5. LUMBRICUS (Earthworm).

In this country there are several species of Earthworm, which differ from one another slightly. The largest is *Lumbricus terrestris.* It and the other kinds are found in damp earth, &c., in which they burrow. The variations in size are very considerable.

MORPHOLOGY.

1. External Characters.—The body is much elongated, and sub-cylindrical. The hinder part is somewhat flattened from above downwards. The symmetry is bilateral, and right and left sides are therefore distinguishable. A *dorsal* surface of dark-reddish colour, and a paler *ventral* surface may also be noted. The body is **segmented**, that is, made up of rings or **segments**, arranged from before backwards. These are very numerous (as many as 200 or 300), and their number is subject to much variation. The segments are largest at the anterior end, where also the *zonitic constrictions*, shallow grooves, of which one (or more) encircles each segment, are most evident. The front end of the body tapers to a blunt point, the apex of which is formed by the small *upper lip* (præstomium). This overhangs the transversely oval *mouth* which is mainly bounded by the first or *mouth-segment* (peristomium). A small longitudinally oval opening, the *anus,* is placed at the posterior end of the body.

The third, like all succeeding segments, has a minute median *dorsal pore,* which communicates with the body-cavity, and is placed in the groove separating the segment from the one in front of it. Every segment, except the first three and the last, possesses a pair of extremely small *excretory apertures* on its ventral surface.

The openings of the hermaphrodite reproductive organs are found on certain of the anterior segments. The largest of these are the *male pores,* the edges of which are somewhat swollen. One opens on each side of the ventral surface of the 15th segment. The much smaller *female pores* are similarly placed in the 14th segment. The four small *spermathecal openings* are placed laterally, one between the 9th and 10th, and another between the 10th and

11th segments, on either side. These openings are sometimes double. The dorsal and lateral regions of some of the segments between 29 and 36 inclusive (in *L. terrestris*, 29-35 inclusive) are thickened into a band known as the *clitellum.*

Running along each side of the body are two double rows of minute, backwardly directed bristles, *setæ.* One row is lateral and placed where the pigment of the dorsal surface shades off, the other ventral. Each segment, therefore, except the first and last, possesses *eight setæ.* The area round the ventral setæ of a few segments in the region of the spermathecal openings is swollen, owing to the presence of the "*capsulogenous glands.*"

2. Skin.—The body is covered by a delicate, horny *cuticle,* which is iridescent, owing to the existence of ridges arranged in two series which cut each other at a high angle. Numerous highly refracting dots are present, which may be due to enclosed matters. The cuticle is formed by the underlying *epidermis,* which is made up of a single layer of nucleated columnar cells. Many of these are unicellular glands, of the type known as *goblet-cells,* which are oval in shape owing to a swelling-up produced by the secretion of some substance in the cell-protoplasm. The epidermis also lines the deep narrow pouches, or *setigerous sacs,* in which the setæ are formed. The lining-cells of these are very small. The setæ are hardened, curved, cuticular structures, which project at the surface for only about one-fifth of their length. Each sac contains a full-sized bristle, and one or two small undeveloped ones. Delicate muscular bands pass from the sacs to the body-wall. In the spermathecal region some of the ventral setigerous sacs are much enlarged. These are the so-called *capsulogenous glands* in which setæ of peculiar shape are formed.

The epidermis is much thickened and very glandular in the clitellum, which also contains a network of blood-vessels.

3. Digestive Organs (Fig. 99, A).—The alimentary canal is a straight tube, of varying calibre, traversing the centre of the body. The *mouth,* for which the præstomium and peristomium form upper and lower *lips,* leads into a small, thick-walled, eversible *buccal pouch* (*b.p*). This is connected by muscle-fibres with the wall of the body in front of it. The walls of the *mouth-cavity* contained in the pouch are raised into numerous folds. Next follows the oval *pharynx* (*ph*) which is placed in segments 3-6.

It is very thick-walled, and connected by numerous radiating, retractor muscle-fibres with the body-wall. Longitudinal ridges project into its cavity. The posterior end of the pharynx is continued into the tubular *gullet* or *œsophagus* (*œ*) which occupies segments 7-14, and may bulge out slightly in several of them. Three pairs of *œsophageal* or *calciferous glands* (*œ.gl*) are present, in segments 10, 11, and 12 respectively. They are good-sized

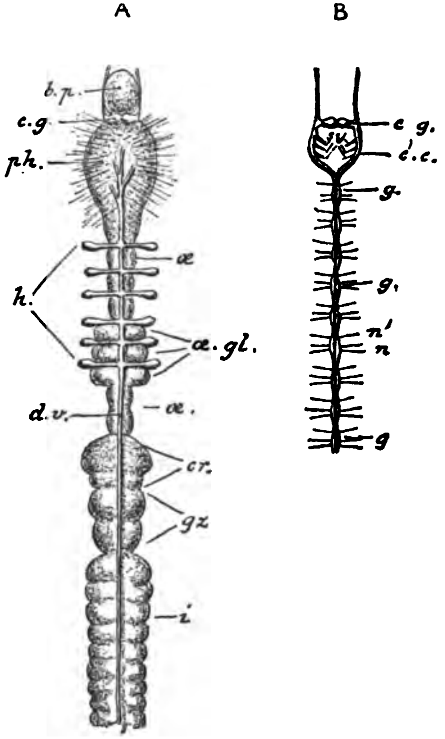

Fig. 99.—Digestive and Circulatory Organs and Nervous System of Earthworm.—A, Digestive and circulatory organs; *b.p*, buccal pouch; *ph*, pharynx; *œ*, œsophagus; *œ.gl*, œsophageal glands; *cr*, crop; *gz*, gizzard; *i*, intestine; *c.g*, cerebral ganglia; *h*, hearts; *d.v*, dorsal vessel. B, nervous system; *c.g*, cerebral ganglia; *c.c*, circumœsophageal commissure; *g,g*, ganglia of ventral cord; *n*, nerves, from ganglia; *n'*, nerves, from between ganglia; *sy*, sympathetic nerves.

pouches usually opening into the œsophagus. The cavities of the last two pairs are divided into numerous compartments. These two pairs may be absent or their cavities may not open into the œsophagus. They appear to be of a different nature from the anterior pair. About segments 15 and 16, the œsophagus expands into a rounded chamber, the *crop* (*cr*), with rather thicker walls. Behind this comes the thick-walled *gizzard* (*gz*) of similar shape, extending back to about segment 19. The rest of the alimentary canal is formed by the thin-walled *intestine* (*i*), which dilates slightly in each segment. Its dorsal wall is pushed in, so to speak, and forms a broad, longitudinal ridge, the *typhlosole*, which projects into the intestinal cavity from its dorsal side. Its surface is raised into close-set transverse ridges. The outside of the intestine is covered by a thin layer of yellowish-brown cells, which also fill up the cavity of the typhlosole. These form the so-called *liver*, or *botryoidal tissue*.

The alimentary canal is contained in the *cœlom* or *body-cavity*, which is split into compartments corresponding to the segments, and separated imperfectly from one another by thin partitions, the *mesenteric septa*, which are perforated below. These septa are firmly united to the alimentary canal, which they hold in place.

Histology.—The alimentary canal is lined with simple columnar *epithelium*, the surface of which is covered by a cuticle, very delicate in the intestine, thicker in the other parts, especially the gizzard. In the œsophageal glands "calciferous-cells" are present, which are apparently derived from the epithelium. A *sub-epithelial* layer now follows, composed of connective-tissue (which tissue, from the Earthworm upwards, contains comparatively few cells, being mostly composed of delicate fibres), in which is a network of blood-vessels. Externally is a *muscular layer*, composed of an internal sheet of circular, and external sheet of longitudinal fibres. The muscle layer is thicker, and has a more complicated arrangement in the pharynx, crop, and gizzard than elsewhere. The *liver-cells* are elongated and oval, with well-marked nuclei, and granular protoplasm. They are closely connected with the blood-vessels.

4. Circulatory Organs (Fig. 100, A).—These place the different parts of the body in communication as regards oxygen and the products of digestion and destructive metabolism. They may be divided into (1) Blood System, (2) Lymph System.

(1.) **Blood System.**—This is made up of a closed series of tubes containing bright red *blood*, in which are contained minute flattened nucleated cells, the *blood-corpuscles.* The red fluid in which these are suspended is known as *plasma.* The blood, after death, or on removal from the body, *coagulates—i.e.*, sets into a jelly-like mass.

Running in the median line on the dorsal side of the alimentary canal is the *supra-intestinal* or *dorsal vessel* (*d.v*). This breaks up in front into a network of small vessels on the pharynx. A much smaller *sub-intestinal vessel* runs longitudinally below the alimentary canal. Longitudinal *supra-neural* and *sub-neural vessels* run above and below the nerve-cord. The latter and two small *lateral neural vessels*, placed one on either side, are imbedded in the sheath of the cord. These longitudinal trunks are connected by transverse *lateral vessels*, the typical arrangement of which in a segment of the intestinal region is as follows:—A *commissural vessel*, giving off numerous twigs to the body-wall, connects the supra-intestinal and sub-neural trunks. Numerous short cross channels connect the sub-intestinal and supra-neural trunks, while others pass between the lateral-neural and sub-neural vessels. The intestine is supplied by numerous branches from the sub-intestinal, which break up into a network, from which the blood returns by two branches to the supra-intestinal. The nephridium possesses a very rich plexus of vessels, supplied by a branch from the supra-neural and sending one to the sub-neural.

In the œsophageal region differences occur, the most important of which consists in the presence of the so-called *hearts* (*h*). These are six pairs of large lateral vessels in segments 6-11, which connect the supra-intestinal and supra-neural trunks, and are closely attached to the anterior faces of the septa.

(2.) **Lymph System.**—This consists of the body-cavity, which is imperfectly separated into compartments, and communicates with the exterior by the dorsal pores. It contains a milky coagulable fluid, the *lymph*, in which are numerous *lymph-corpuscles*, irregular nucleated cells, with granular protoplasm, capable of amœboid movements. The body-cavity is lined by *endothelium, i.e.*, epithelium composed of a single layer of flattened nucleated cells.

5. **Excretory Organs.**—Each segment, with the exception of the first three and the last, contains a pair of *nephridia*, or *seg-*

mental organs. The nephridium on either side is a tube, of varying calibre in its different regions, attached by a membranous flap to the back of the septum bounding the front of the segment. It is thrown into numerous folds running parallel to the septum in a vertical direction, and commences with a *ciliated funnel* which lies in the *preceding* segment. The stalk of this pierces the septum, and passes into an extremely narrow *thin-walled part,* which describes three loops, two short and one long, and then merges into the much thicker *glandular part,* thrown into a long and short loop parallel to the preceding. The dorsal part of the long loop is much thicker than the rest. The last, or *muscular part,* of the tube is thicker than the rest, and after being bent once upon itself, opens to the exterior by a minute pore just in front of the ventral setæ.

Histology.—The *funnel,* which opens into the body-cavity, is lined by ciliated epithelium. The *glandular part* is lined by epithelium which is partly ciliated and partly glandular, the cells of the latter kind being large and granular. This portion of the nephridium has a rich blood-supply. The *muscular part* is non-glandular, and its walls contain numerous muscle-fibres.

6. **Reproductive Organs** (Fig. 100).—The Earthworm is hermaphrodite, like the Fluke, but its sexual organs are less complicated. They vary much in size, according to the time of year, being largest in the summer, which is the breeding-season. The segments in which they are placed are anterior to the clitellum. Their colour is white, and they lie for the most part below the alimentary canal, in its œsophageal region.

(1.) **Male Organs.**—There are two pairs of minute flattened *male gonads* or *testes* (*see Fig.* 100), produced into finger-like processes behind. These are attached, near the nerve-cord, to the back of the septa forming the anterior boundaries of segments 10 and 11. In the sexually mature state they project into the cavities of the seminal reservoirs. The most conspicuous parts of the male apparatus are the *vesiculæ seminales* (V.S.), two pairs of large white pouches in segments 9-12 (formerly mistaken for the testes), which may completely overlap the œsophagus. The anterior pair is deeply bilobed, uniting into a median seminal reservoir in segment 10. The posterior pair is folded, uniting into a similar structure in segment 11.* Projecting into the floor

* In young specimens the vesiculæ of opposite sides are quite distinct.

of each reservoir is a pair of large plicated *seminal funnels*, turned towards the testes. From each funnel a delicate tube, the *vas efferens*, proceeds, which, after forming a coil, takes a backward

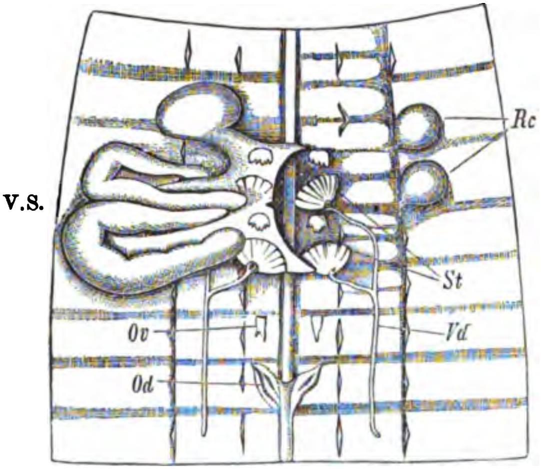

Fig. 100.—REPRODUCTIVE ORGANS OF EARTHWORM (from *Claus*, after *Hering*).—Segments 8 to 15 opened, and alimentary canal removed. The nerve-cord is seen running down the centre, and the septa are represented by transverse bands. V.S., Vesiculæ seminales, those on right side removed. St., Funnels of vas deferens, near which are seen small testes with notched posterior margins. V.d, Vas deferens. Ov, Ovaries. Od, Oviducts (inadequately represented). Rc, Spermathecæ of right side.

course. The two vasa efferentia on either side unite together in segment 12 into a straight tube, the *male gonaduct* or *vas deferens* (V.d), which passes back through segments 13 and 14 to open by the male pore in segment 15. This is just external to the ventral setæ.

(2.) **Female Organs.**—The *female gonads* or *ovaries* (Ov) are two pear-shaped bodies, rather larger than the testes, and having a similar position in segment 13. Their narrow ends are directed backwards. The *female gonaducts* or *oviducts* (Od) are short, wide tubes, with dilated funnels, lying mainly in segment 14, on the ventral surface of which they open by the *female pores*, much smaller than the male pores, but occupying a similar position.

The funnels pierce the septum between segments 13 and 14, projecting into the cavity of the former. Each oviduct is dilated near its commencement into a *receptaculum ovorum*, a pouch in which the ova may temporarily accumulate. The *spermathecæ* (receptacula seminis) are two pairs of rounded sacs, lying usually in segments 9 and 10 (Rc). They open laterally between segments 9 and 10, and 10 and 11, just on a level with the lateral setæ. Their apertures may be double.

Histology.—The *testis* (like all gonads) may be regarded as a thickened and specialized part of the epithelium lining the body-cavity. It contains numerous *germinal-cells* which, as *spermatospores*, pass into the seminal reservoir. Here they segment, to produce *sperm-morulæ*, each of which contains a central passive part covered by numerous small cells, *spermatoblasts*, which become *spermatozoa*. These possess a long cylindrical head and vibratile tail. They remain for some time attached by their heads (the altered nuclei of the spermatoblasts) to the passive part of the morula, but are finally liberated.

The *ovaries* have a similar structure to the testes. The germinal cells which they contain develop into ova. Each ovary contains many ova in different stages of development, the ripest being at the free end. The *ovum* is spherical in shape, and covered externally by a delicate *vitelline membrane*. The granular *vitellus* contains a clear *germinal vesicle*, with *germinal spot*. The ripe ova burst out of the ovary into the body-cavity, and are taken up by the funnels of the oviduct, which are ciliated.

(3.) **Accessory Organs.**—The clitellum and capsulogenous glands are connected with the reproductive function.

7. **Muscular System.**—The muscular tissue connected with the alimentary canal and nephridia has already been mentioned. The walls of the larger vessels, especially the hearts, also contain muscle-fibres.

As in the Fluke, most of the muscle is found in the body-wall. A continuous *circular layer* underlies the skin. In this the pigment which gives the dorsal surface its characteristic tint is imbedded. Delicate bands, the *protractor muscles* of the setæ, pass from this layer to the inner ends of the setigerous sacs. Beneath the circular layer is a *longitudinal layer* of about the same thickness. This is subdivided into longitudinal bands, a broad *dorsal* band, between the two rows of lateral setæ, a much narrower *ventral* band between the ventral setæ, a *lateral* band of about the same width between the lateral and ventral setæ on either side, and finally four excessively thin strips (two *dorso-lateral* and two *ventro-lateral*), one between the setigerous sacs in each double row. Each band is made up of plates, perpendicular to the circular layer, in which the fibres are arranged so as to give a feather-like appearance in cross-section. Connected with the longitudinal layer are delicate *retractor muscles* of the setæ, attached to the setigerous sacs where they reach the middle of the circular layer.

The septa contain muscular fibres, imbedded in much connective-tissue, and taking various directions. They are covered by the endothelium of the body-cavity, with which also the longitudinal muscle layer is lined.

Histology.—The muscle-fibres are elongated spindle-shaped cells. They are united together by their tapering ends.

8. **Nervous System** (Fig. 99, B).—Lying on the dorsal surface, at the point where the buccal pouch and pharynx unite, are two pear-shaped *cerebral ganglia* (*c.g*, A and B), closely connected by their broad ends. From each a *circumœsophageal commissure* (*c.c*) runs downwards and backwards to unite with its fellow in the middle line. There is a ganglion, the *first ventral ganglion*, at the point of union. A *nerve-ring* is thus formed, encircling the junction of the buccal pouch and pharynx. From the ventral ganglion a *ventral nerve-cord* passes backwards to the end of the body, in the median line, just above the body-wall. It dilates slightly into a *ventral ganglion* (*g*) in each segment. The nerve-cord is made up of two closely united halves. This is indicated by a longitudinal furrow running along its upper surface.

A nerve passes from each cerebral ganglion to the præstomium and peristomium. The second segment is supplied by nerves from the outside of the commissures, and the third segment receives branches from the first ventral ganglion, lying in the front part of segment 4, which it also partly supplies. The second ventral ganglion lies in the middle of segment 4, to which it gives off two pairs of nerves. Each segment behind this possesses three pairs of nerves, two arising from its ganglion (*n*), and one from the cord in front of this (*n′*).

A number of delicate nerves pass from the inner sides of the commissures to the pharynx, within which they form a plexus. This arrangement is called the **sympathetic nervous system** (*sy*).

Histology.—The central nervous system is enveloped in a connective-tissue *sheath*, the centre of which is traversed by numerous longitudinal muscle-fibres. Above the ventral cord three tubular *giant fibres* run in the sheath, and so do the subneural and lateral neural vessels below and at the sides. As in the Fluke, the two nervous elements are *ganglion-cells* and *nerve-fibres.* The former are produced into a process which branches copiously. They are not confined to the ganglia, but scattered throughout the whole central nervous system, ventrally and laterally.

PHYSIOLOGY.

1. **Nutrition.**—The Earthworm lives principally on vegetable food, but animal substances can be used as well. Earth is swallowed largely for the sake of the contained organic matter. Pieces of leaf, &c., are partially digested before being taken into the body by a fluid poured on to them from the mouth, and apparently secreted by the epithelium lining the buccal pouch. Food is taken in by a sucking action of the pharynx, and organic acids contained in it are neutralized by carbonate of lime secreted in the œsophageal glands.

This lime may also be regarded as an excretion. A superabundance of it is taken in with the food, and is thus got rid of.

Food accumulates in the crop, and is then passed on to the gizzard, where the contractions of that organ grind it up. This process is largely helped by small stones which have been swallowed and act as millstones. The contractions of the muscular wall of the intestine causes the substances which enter it to be passed slowly backwards. They are meanwhile subjected to the action of a digestive juice, similar to that poured from the mouth, and probably secreted by the intestinal epithelium. This apparently contains a *ferment* * (*see p.* 12), which brings the starch and proteids into a state of solution, the former being converted into grape-sugar, the latter into peptones. Any fat swallowed is brought into a very fine state of division—*i.e.*, emulsified. These reactions can only take place in an alkaline solution, hence the use of the œsophageal glands.

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* **Ferments** are bodies which excite chemical changes in other bodies without themselves entering into the reactions. They are (1) *Living—e.g.*, Yeast and Bacteria; (2) *Non-living—e.g.*, digestive ferments, complex nitrogenous bodies found in digestive fluids.

The so-called "*liver*" appears to have nothing to do with digestion, but the matter is still rather doubtful.

The undigested remnants are passed out from the anus as cylindrical "worm-castings." These form little heaps on the surface of the ground, and as they are composed of earth brought from below, a mixing of soil is gradually effected.

The intestine, partly owing to the presence of the typhlosole, offers a large absorbent surface to the digested materials. The products of digestion readily pass into the blood-vessels ramifying in the intestinal wall, and are thence distributed to the body at large. Owing mainly to the regular contraction of the walls of the hearts from above downwards, a general **circulation** of the blood is brought about. It passes into the hearts from the dorsal vessel, which receives it by some of the lateral trunks, and from them into the longitudinal vessels on the ventral side of the body. The ends of the vascular twigs break up into a delicate thin-walled network, from which the nutritious parts of the blood can readily diffuse into the surrounding tissues.

2. Destructive Metabolism.—(1.) There are no special organs of **respiration.** This function is effected by the general surface of the body, the carbon dioxide diffusing out of the blood-vessels underlying the skin, and oxygen diffusing into them. The red colour of the blood is due to *hæmoglobin,* a complex compound of carbon, hydrogen, oxygen, nitrogen, sulphur, and iron, which enters into loose combination with the oxygen taken into the body, readily parting with it again to the tissues.

(2.) **Excretion.**—Water can be excreted by evaporation from the *skin,* and can also pass out of the body-cavity (with the other part of the lymph) by the *dorsal pores,* which can be opened by special muscle-fibres. The nephridia are concerned with the excretion of water and nitrogenous waste. The former enters them by the ciliated funnels, the latter is probably excreted by the glandular part of the lining epithelium which separates it from the blood with which these organs are richly supplied. The *urine,* as the excreted substances may be collectively termed, passes down the nephridia by the action of the cilia, and it can be more vigorously expelled from the muscular parts by their contraction.

3. **Reproduction.**—Although the Earthworm is hermaphrodite, self-fertilization is not effected, two individuals copulating, and fertilizing each other. This occurs on the surface of the ground during the warm summer months. The two become closely applied by their ventral surfaces, their heads being in different directions. Adhesion is effected by the modified setæ of the capsulogenous glands, and the overlapping of the edges of the clitellum, which in each worm extends over the spermathecal openings of the other. The sperm passes back from the male pores of either worm to the spermathecæ of the other, in which it is stored up.

The ova are laid in horny capsules, probably formed by the hardening of a fluid secreted by the clitellum. In *L. terrestris* many ova are passed into each capsule, together with some sperm (derived from another individual) from the spermathecæ. In some worms *polar cells* (Fig. 93) have been noticed in connection with the ovum, and they are probably present in the Earthworm. Fertilization (Fig. 94) takes place in the egg-capsules.

4. **Contractility.**—**Amœboid movement** is shown in the lymph-corpuscles, and **ciliary action** in the nephridia and oviducts. The action of **muscles** surrounding cavities has already been exemplified as regards the digestive, circulatory, and excretory organs, food being taken in, ground up, and passed backwards, blood regularly propelled, and urine expelled respectively. Locomotion, as in the Fluke, is effected by the dermal musculature, the anterior part of the body being advanced by the contraction of the circular muscle, when, the anterior setæ serving for attachment, the hinder part is dragged up by contraction of the longitudinal layer. The reverse movement can also be effected, and complex curves can also be described. The direction and amount of protrusion of the setæ are regulated by their protractor and retractor muscles.

The muscular contractions are largely due to impulses conveyed to them from the central organs by motor nerve-fibres.

5. **Irritability and Spontaneity.**—The nerve-ring and cord, in virtue of their ganglion-cells, are the central organs. Each segment is regulated to a certain extent by the small part of the nervous system contained within it. The cerebral ganglia are

the chief seat of spontaneity, and regulate the body as a whole. The nerve-fibres are afferent and efferent. The pharynx is probably controlled by the sympathetic system, subject to the influence of the central organs.

Special senses appear to be present, although there are no special sense-organs. The whole surface of the body possesses the sense of *touch,* while *taste* and *smell* are apparently localized in the peristomium and præstomium. All trace of *hearing* seems to be absent. Although the Earthworm can hardly be said to have *sight,* yet light affects the anterior end of the body, probably by acting directly on the cerebral ganglia through the translucent body-wall.

DEVELOPMENT.

1. **Early Stages.**—In *L. terrestris* the **segmentation** is nearly regular. It leads to the formation of a vesicle or *blastosphere,* with a wall one cell thick. The contained cavity is the *segmentation-cavity.* The *blastosphere* is flattened, and the cells on one side are clearer than those on the other. These clear cells make up the *hypoblast,* the others the *epiblast.* The hypoblastic side of the vesicle is pushed in, **invaginated,** so that the epiblast comes to be external, and the segmentation-cavity is obliterated. The embryo is now a cylindrical *gastrula,* that is, a sac with a double wall, formed externally of **epiblast,** internally of **hypoblast.** The cells of the latter line the cavity of the gastrula, which is the first rudiment of the alimentary canal, and is termed the *arch*-enteron. The embryo exhibits bilateral symmetry at this stage, and has dorsal and ventral surfaces. The archenteron opens by a longitudinal slit, the *blastopore,* upon the ventral surface. This closes up behind, but a small aperture, the *mouth,* is left at the front end. The *anus* is formed much later as a perforation. The epiblast extends inwards for a short distance at these points. In Hydra there are only *two* embryonic layers, the epiblast and hypoblast; but here a third layer, the *mesoblast,* comes into existence between the other two.

Mesoblast no doubt exists in the Fluke, but there is a gap in our knowledge between segmentation and the free embryo.

Two **mesoblastic bands,** derived probably from the epiblast, are found, one on either side of the embryo.

2. **General Growth.**—For some time the embryo is concave dorsally, and convex ventrally, but it gradually elongates and assumes the characters of the adult. Only one ovum in a capsule usually developes. The others serve as food.

3. **Fate of the Germinal Layers.**—The **epiblast** gives rise to the epidermis and the epithelial lining of the buccal pouch, pharynx, and œsophagus. Thickenings of the epiblast, which are separated off and come to lie within the body-wall, form the nervous system.

The **hypoblast** produces the epithelium of the alimentary canal behind the œsophagus.*

The two bands of **mesoblast** unite in front above the mouth. They become split up transversely into squarish blocks, *mesoblastic somites,* which correspond to the segments. In each somite a cavity appears, which possesses four walls—anterior, posterior, external (somatic), and internal (splanchnic). The somites grow both dorsalwards and ventralwards, fusing where they meet, and thus completely encircling the body. The septa are formed by the union of anterior and posterior walls of adjacent somites. The nephridia grow out from the posterior sides of the septa, afterwards becoming connected with the exterior. The cavities in the somites ultimately communicate with one another and form the body-cavity. The splanchnic walls originate the muscle and connective-tissue of the alimentary canal, and the main vascular trunks, whilst the dermal musculature arises from the somatic walls. The reproductive organs are also derived from the mesoblast.

* In a form like Hydra the archenteron persists through life as the digestive cavity, and the blastopore as the "mouth," while there is no separate *body-cavity.* But in forms possessing mesoblast the alimentary canal is commonly divisible into *fore-gut* (stomodæum), *mid-gut* (mesenteron), and *hind-gut* (proctodæum), while a *body-cavity* is present. The *mid-gut* is lined by hypoblast and derived from the archenteron, of which the body-cavity is also considered a derivate. The fore- and hind-guts arise as depressions in the epiblast, and are of course lined by that layer. Hydra and the Earthworm may therefore be compared as follows:—

Hydra.	**Earthworm.**
O	*Fore-gut* (buccal pouch + pharynx + gullet).
O	*Hind-gut* (a very small part close to anus).
Archenteron =	*Mid-gut* (crop + gizzard + nearly all intestine). *Body-cavity.*

CHAPTER IV.—ARTHROPODA.

§ 6. ASTACUS (The Crayfish).

The Crayfish is a small lobster-like animal, living in clear rivers. An average mature specimen is about five inches long. There is only one British species, *Astacus fluviatilis*, but a rather larger kind, *A. nobilis*, is common on the Continent. As the points of difference are but small, the following description will apply to either.

MORPHOLOGY.

1. External Characters. (Figs. 101, 102, and 103).—The bilaterally symmetrical body is *segmented*, as in the Earthworm, but the segments are definite in number, and, instead of being nearly all alike, vary much in character, and many of them are fused together. Owing to these differences the body is marked out into regions from before backwards, *head*, *thorax*, and *abdomen* or tail. The two first are united together as the *cephalothorax*, which is covered by a firm continuous shell, the *carapace*, dorsally and laterally. The segments of all the regions bear paired, jointed *appendages* of various kinds.

(1.) The **abdomen**, as the least modified part, affords a convenient point of departure for study. It is made up of seven segments, movably united together, and broader in the female than the male. The first six of these bear appendages known as *swimmerets* (Fig. 103, K, L, M). The abdominal region, like all the rest of the body, is covered by a firm *exoskeleton* of chitinous nature. This is largely calcified, but uncalcified parts remain, and joints are thus formed. The 3rd, 4th, and 5th abdominal segments are most typical, and alike in both sexes. The exoskeleton of each of these segments consists of a calcified ring connected by uncalcified parts with the segments in front and behind. The broad, strongly convex dorsal and lateral part of the segment is the *tergum* (*t*). The front part of this is overlapped by the preceding tergum, and its hinder part overlaps the succeeding one. Small elevations on the front of the tergum, one on either side, fit into small pits belonging to the preceding segment, firmness being thus secured. The tergum passes down on either side into a small pointed flap (*pl*), the *pleuron*

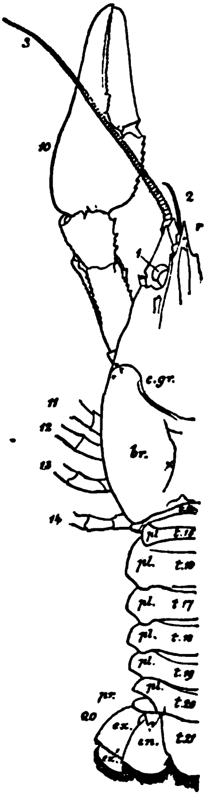

Fig. 101.

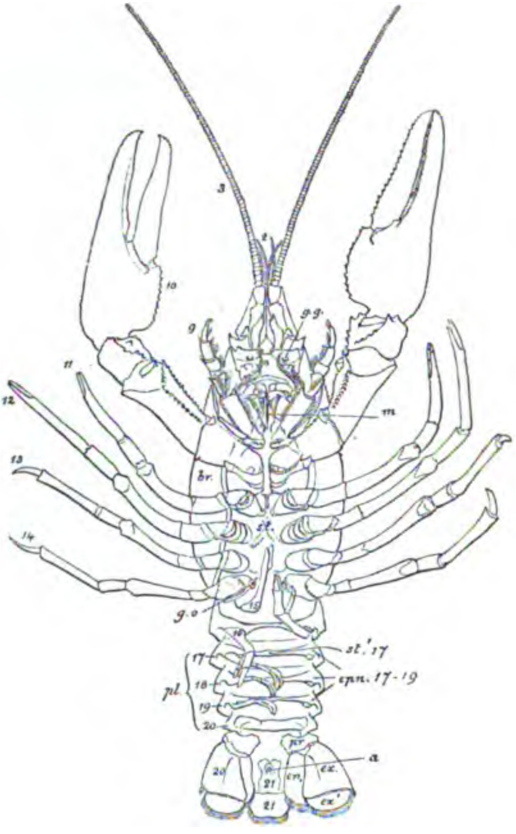

Fig. 102.

Fig. 101.—Top View of Male Crayfish (Reduced).—1-3, 10-14, and 20, appendages; *pr*, protopodite; *en*, endopodite; *ex*, *ex'*, exopodite; *pl*, pleura; *br*, branchiostegite; *c.gr*, cervical groove; *r*, rostrum; *t*, 14-21, terga; ×, placed on branchio-cardiac groove.

Fig. 102.—Under View of Male Crayfish (Reduced).—2, 3, 9-16, and 20, appendages; *pr*, protopodite; *ex*, *ex'*, exopodite; *en*, endopodite; 21, telson; *br*, branchiostegite; *pl*, 17-20, pleura; *epn*, 17-19, epimera; *st*, sterna; *g.g*, excretory aperture; *m*, mouth, with jaws and foot-jaws; *g.o*, genital opening; *a*, anus.

(larger in the female), which is V-shaped in section, being made up of an outer and inner limb. On the under side of the segment is a narrow transverse bar, the *sternum* (*st*). Broad uncalcified intervals, the *intersternal membranes*, separate adjacent sterna. The *sternum* passes on either side into a very short but broader *epimeron* (*epn*), the junction between the two being marked by the attachment of the appendage. The foregoing parts form a perfectly continuous ring. There are no sharp lines of demarcation, and the names are given for convenience in description.

Each of the *swimmerets* (Figs. 102 and 103, M) is a small elongated body, consisting of a proximal stalk, the *protopodite* (*pr*), and two distal branches, an internal *endopodite* and external *exopodite* (*ex*). An inverted λ serves as a diagram of the arrangement.

The *proximal* and *distal* ends of an appendage, &c., are the ends respectively further from and nearer to its free end.

The *protopodite* is made up of a very short annular proximal and a stouter distal joint. The *endopodite* and *exopodite* both possess a relatively long proximal joint, and a rather longer distal part imperfectly divided into rings. All parts of the swimmeret are more or less beset with stiff hairs or *setæ*.

The 6th abdominal segment (20 in Figs. 101 and 102) differs from the preceding, mainly in the great size of the swimmerets. The protopodite is broad, thick, and one-jointed, while the endopodite and exopodite are very broad, oval, hair-fringed plates, the latter two-jointed. The 7th abdominal segment or *telson* (21) possesses neither pleura nor appendages.* It is divided into two by an imperfect transverse joint. Upon its little-calcified sternal surface the *anus* (*a*) opens, a longitudinal slit with thickened edges. The telson and large 6th pair of swimmerets make up together the *tail-fin*. The 1st and 2nd abdominal segments mainly differ in the character of their appendages, but in addition to this the former is small, possesses no pleura, and hinges on to the cephalothorax in a somewhat complicated manner. In the *female*, the 2nd pair of swimmerets are normal, the 1st pair rudimentary or absent. Both these pairs are modified in the *male* into *copulatory organs* (Fig. 102, 15 and 16; Fig. 103, K and L). The proximal joint of the endopodite is produced into a plate rolled upon itself in the second (16 and L); while the first (15 and K) are two-jointed rods (protopodite and endopodite) with the usual annular proximal joint, and an elongated distal joint, the end of which is flattened and scroll-like.

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* The telson is not regarded as a segment by all morphologists.

In the *cephalothorax* (Figs. 101 and 102) the terga and pleura are fused into a continuous carapace, produced in front into a sharp spine, the *rostrum* (*r.*) On the upper surface of the carapace is a transverse groove, which slopes downwards and forwards to its front edge. This *cervical groove* (*c.gr*) marks the boundary between the head and thorax.

(2.) The **thorax** is composed of eight fused segments, the last of which is slightly movable. The *tergal region* is rather narrow, and its lateral boundaries are indicated in front by a *branchio-cardiac-groove* (×) running back from the cervical groove. The pleura are extremely large, and fuse on either side into a flap, the *branchiostegite* (*br*), which curves outwards and downwards to the bases of the thoracic appendages. It is united with the head along the cervical groove. The *epimera* are very large and thin. They form on either side a plate sloping steeply downwards, which forms the inner wall of the *gill-chamber*. Grooves converging upwards mark the boundaries of the segments. The outer wall of this chamber is the branchiostegite. The thoracic sterna (*st*) are narrow elongated plates, lying between the bases of the appendages, and, except the last, closely united together. The last four of these appendages are elongated *walking-legs* (11-14), the two first of which are *chelate*, *i.e.*, with pincers, and possess no exopodite. The two-jointed protopodite is continuous with a five-jointed endopodite, the penultimate joint of which, in the two first, is produced distally alongside the ultimate joint, which works against it to form a claw. The broad proximal joint of the protopodite bears in the first three walking-legs a membranous plate, the *epipodite* (*ep.*, I., Fig. 104), which projects into the gill-chamber, and on which gill-filaments are arranged in a plume-like way. The *male genital pore* (*g.o*) is placed on the inner side of the proximal joint of the protopodite of the last walking-leg. The *female genital pore* is found in a similar position on the second walking-leg.

The fourth pair of thoracic appendages are the large *forceps* (10). These are similar in structure to the chelate walking-legs, but their claws are very much larger, and the distal joint of the protopodite is firmly fused with the proximal joint of the endopodite. The first three pairs of thoracic appendages are relatively small and flattened, and are termed *foot-jaws* (maxillipedes). The *third* (external) pair (Fig. 103, H) have a two-jointed protopo-

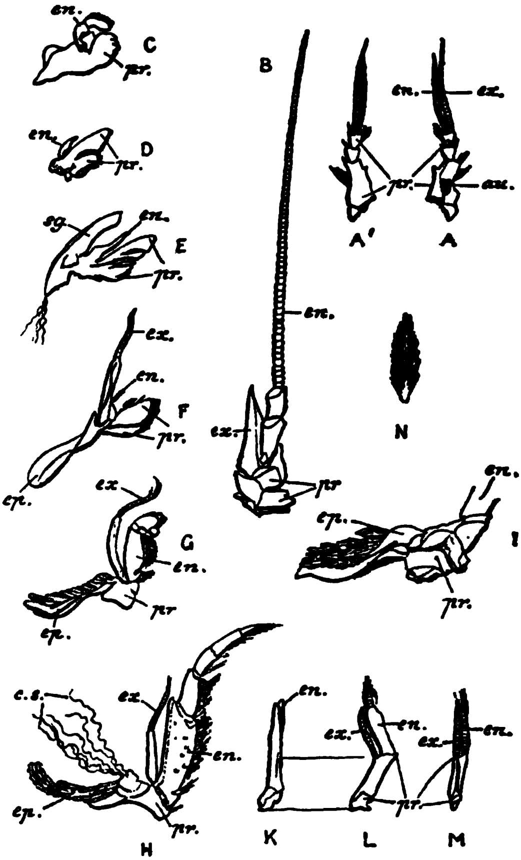

Fig. 103.—Appendages of Astacus, Right side (Eyestalks omitted).—A and A′, Upper and lower views of antennule; B, antenna; C, mandible; D, mx. 1; E, mx. 2; F, mxpd. 1; G, mxpd. 2; H, mxpd. 3; I, base of third walking-leg; K and L, 1st and 2nd male swimts.; M, typical swimt.; N, arthrobranchia; *pr*, protopodite; *en*, endopodite; *ex*, exopodite; *ep*, epipodite; *c.s*, coxopoditic setæ; *sg*, scaphognathite; *au*, auditory opening.

dite, the distal joint of which is firmly fused with the proximal joint of the five-jointed endopodite. The protopodite and proximal part of the endopodite are notched internally, and provided with stout setæ. The terminal part of the latter is curled round towards the middle line. An epipodite with gill-filaments is present, and also a slender exopodite, resembling those of the swimmerets, but larger. The third foot-jaws overlap the *second foot-jaws* (G), which are quite similar in structure, but smaller and weaker, while the exopodite is larger in proportion, and there is no fusion between the endopodite and protopodite. The *first foot-jaws* (F), which are covered by the second, are small and flat. The two joints of the protopodite are thin hair-fringed plates; the endopodite is a minute filament, and the epipodite bears no gill filaments.

(3.) The head is probably made up of six segments closely united. That part of the carapace in front of the cervical groove represents the terga. It is produced in front into the rostrum, on either side of which is a deep notch, in which the stalked eye (1) is placed. The stalk is two-jointed, and is perhaps the appendage of the 1st head-segment. If so, endopodite and exopodite are absent. This region is much broader than the corresponding thoracic one, hence it bounds the front of each gill-chamber. The pleural region is rudimentary, and represented by the edge of the carapace, while the epimera and sterna are small, and not easily made out. On the sternal surface, between the 4th and 5th segments, is the elongated and slit-like mouth (*m*) with a bilobed lower lip, the *metastoma* (Fig. 104, A, *mt*), and an overhanging pointed upper lip, the *labrum* (Fig. 104, A, *lb*), both of which are supported by calcareous plates. In front of the mouth the sternal region is sharply bent up. Owing to this *cephalic flexure*, the anterior appendages are directed forwards (*compare Fig.* 104, B). The last three pairs of head-appendages are small jaws, covered over by the foot-jaws. The most posterior are the *second maxillæ* (Fig. 104, E), which resemble the first foot-jaws, but are more delicate and possess no exopodite. The two thin plate-like joints of the protopodite are deeply cleft. The epipodite is a large elongated plate, which lies in the front of the gill-chamber, and has received the special name of *scaphognathite* (*sg*). These appendages overlap the still weaker *first maxillæ* (D), which are devoid of endopodite. The two joints of the protopodite are not cleft.

Lying just outside the mouth are the *mandibles* (C), in which exopodite and epipodite are absent. The protopodite is a firm, transversely elongated structure, the inner end of which possesses two strongly toothed ridges. The endopodite is a small three-jointed palp.

The forwardly-directed appendages of the 3rd segment are the *antennæ* (B). These consist of a protopodite with two stout cylindrical joints, the proximal of which has a small tubercle on its under surface, upon which is the *excretory* or *renal aperture* (*see Fig.* 104, B). To the protopodite a scale-like exopodite, the "squame," is attached externally, and a very long-jointed endopodite, or "feeler," internally. This is composed of two stout proximal joints and a terminal part made up of a great many small rings, imperfectly jointed together. The much smaller *antennule* (A and A′) attached to the 2nd segment, lies rather internal to the antenna, and is directed forwards. The protopodite is three-jointed, and its proximal joint, which is much the largest, abuts against its fellow in the middle line. It is somewhat trihedral, and on its upper surface is a small longitudinal slit (*au*), the *auditory aperture*, over which a horizontal brush of hairs attached to its outer edge projects. The endopodite and exopodite are two short, slender, imperfectly-jointed filaments, of which the latter is rather the longer.

Between the sterna of the thorax and posterior part of the head a number of folds of the exoskeleton project into the body. These *apodemes* are calcified and united together to form a kind of open framework, the *endophragmal system*, which imperfectly roofs over a cavity known as the *sternal canal.*

2. Skin.—The true skin is formed by an *epidermis* with a thin underlying *dermis.* The former secretes the exoskeleton, a many-layered cuticle, differing in degree and not in kind from those of the Fluke and Earthworm, and largely impregnated with salts of lime (seven-eighths carbonate and one-eighth phosphate).

Histology.—The epidermis is one-cell thick, and the outlines of the cells composing it are indistinct. The thin dermis is composed of connective-tissue, in which delicate blood-vessels and nerves run. The exoskeleton is made up of numerous closely-united layers, which are traversed by an immense number of delicate vertical "pore-canals." The setæ are two-jointed hairs attached to small pits in the outer surface. Each is covered by a delicate cuticle, and contains internally a granular axis, which passes through a seta-canal to become continuous with the epidermis.

3. Digestive Organs (Fig. 104, A).—The forceps and clawed walking-legs are accessory to digestion, and the six pairs of jaws overlapping one another outside the mouth are still more closely connected with the same function, and hence receive the collective name of *trophi.* But all these are more or less modified appendages, and outside the alimentary canal.

The *mouth* (*m*), which possesses upper and lower lips (*l* and *mt*), leads into the *fore-gut.* This consists of a short, wide, upwardly-directed *œsophagus* (*œ*), and a large sac, the *stomach,* into which this opens. The stomach fills most of the cavity in the head, and is divided into a larger *cardiac* (*ca*) part in front and a smaller *pyloric* (*py*) part behind. The two are separated by a deep constriction. The whole of the *fore-gut* is lined by a firm cuticle, continuous with the exoskeleton. This is thickened and calcified into plates and bars to form a *gastric mill,* and produced into stiff hairs to constitute a *strainer.* The gastric mill lies mostly in the posterior part of the cardiac division of the stomach. Here there is a broad *cardiac ossicle* (*c.o*) lying transversely in the dorsal wall. Attached to the middle of this is a small *uro-cardiac ossicle,* directed downwards and backwards in the front wall of the dorsal part of the constriction separating the two halves of the stomach. These two ossicles form a T-shaped arrangement. A second and somewhat similar T-shaped combination is formed by a *pyloric ossicle* (*py.o*) (narrower than the cardiac), placed across the dorsal wall of the pyloric part of the stomach. To this is jointed a *pre-pyloric ossicle,* forming the stem of the T, which takes a downward and backward course in the back wall of the constriction above-mentioned, joins the end of the uro-cardiac ossicle, and projects beyond it into the cardiac chamber. This projecting end forms a red-coloured *median tooth,* the tip of which is forked.

From the extremity of the cardiac ossicle on either side a small *ptero-cardiac ossicle* runs back, and unites with a *zygo-cardiac ossicle* that runs forwards from the end of the pyloric ossicle. The inner side of each zygo-cardiac ossicle is thickened into an elongated red *lateral tooth,* which projects into the cardiac cavity. It is marked by numerous transverse ridges.

Two *anterior gastric muscles* (*a.g.m*) take their origin on the inner side of the carapace, and run backwards and downwards to be inserted into the cardiac ossicle, while two *posterior gastric muscles* (*p.g.m*) run downwards and forwards from a similar origin to be inserted into the pyloric ossicle.

In addition to the ossicles forming the gastric mill, others of less importance are found in the cardiac wall; and in summer a round button-like calcareous *gastrolith* is often seen projecting into the cardiac cavity on either side.

The communication between the cardiac and pyloric cavities is very narrow, partly owing to the external constriction and partly to hair-fringed projections. This is the commencement of the *strainer*, the rest of which is formed by hairy cushions projecting into the pyloric cavity and reducing it to a fissure, anchor-shaped in cross-section. A valve composed of five flaps separates the stomach from the mid-gut.

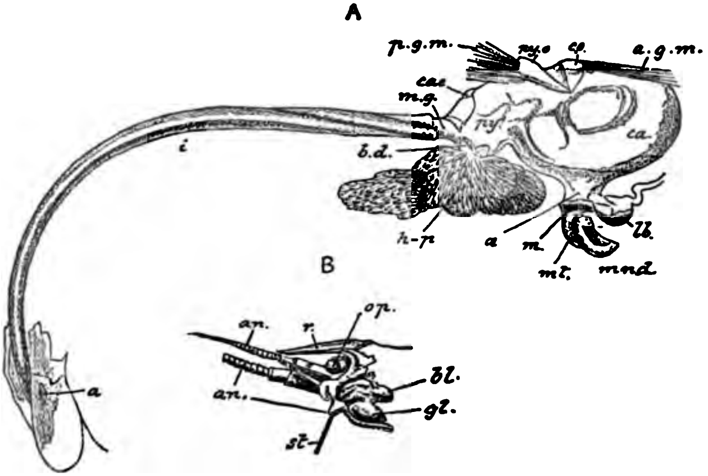

Fig. 104.—Alimentary Canal and Excretory Organs of Crayfish.—A, Alimentary canal; *m*, mouth; *lb*, labrum; *mt*, metastoma; *œ*, œsophagus; *ca* and *py*, cardiac and pyloric ends of stomach; *c.o*, cardiac ossicle, the horizontal shading just below reference-line shows the commencement of the ptero-cardiac ossicle, which tapers to a point below; *py.o*, pyloric ossicle, running into the zygo-cardiac ossicle, which joins the ptero-cardiac; *a.g.m*, and *p.g.m*, anterior and posterior gastric muscles; *m.g*, mid-gut; *cæ*, cæcum; *h-p*, hepato-pancreas; *b.d*, hepato-pancreatic duct; *i*, intestine; *a*, anus. B, Left renal organ; *gl*, glandular part; *bl*, bladder; *st*, style passed into renal opening; *an* and *an′*, antennule and antenna; *op*, eye; *r*, rostrum.

The *mid-gut* (*m.g*) is an extremely short part of the alimentary canal, and is not lined by cuticle. Its dorsal wall is produced upwards and forwards into a short blind tube, the *cæcum* (*cæ*). The mid-gut passes into a small thin-walled tube, the *hind-gut* or *intestine* (*i*), which runs back in the middle line to open by the *anus* (*a*). It is lined by cuticle, and six slightly-twisted longitudinal ridges, covered by minute elevations or *papillæ*, project into its cavity.

Connected with the mid-gut are two large brownish glands. Each of these is a *hepato-pancreas* (*h-p*) or "*liver*." The hepato-pancreas of either side occupies a considerable space on one side of the cephalo-thorax. It is made up of three lobes, anterior, middle, and posterior, and a short, wide *hepato-pancreatic* or "*bile*" *duct* (*b.d*), opens from it into the floor of the mid-gut.

Histology.—The alimentary canal is lined throughout by epithelium, which in the fore and hind guts is covered by a cuticle continuous with the exoskeleton, and in the stomach is thickened and calcified into bars and plates. Outside the epithelium, connective-tissue and muscular layers are present.

Each hepato-pancreas is made up of a very large number of short cæca, lined by glandular epithelium. In each lobe these open into a central duct, and the three central ducts unite to form the hepato-pancreatic duct.

4. Circulatory Organs.—There is no distinction as in the Earthworm between blood and lymph systems, and the former name is applied to the whole circulatory apparatus.

The *blood* is almost colourless, and consists of plasma, in which are numerous *white corpuscles*, quite similar to the lymph-corpuscles of the Earthworm.

On the dorsal side of the thorax is a good-sized *pericardial sinus*, in which the *heart* is suspended by fibrous cords. This organ is a flattish, thick-walled sac, in whose walls are three inwardly-opening pairs of valvular apertures. These three pairs of *ostia* are dorsal, lateral, and ventral, respectively. From the heart a number of delicate *arteries* proceed.

An *artery* carries blood from—a *vein* towards, the heart.

From the front of the heart a small unpaired *ophthalmic artery* runs forwards and divides to supply the eye-region. On either side of this arises a much larger *antennary artery* which passes to the antenna, giving off branches to the stomach and renal organ during its course. A little behind each antennary artery, and somewhat ventrally, a *hepatic artery* takes origin, which supplies the mid-gut and hepato-pancreas. The posterior end of the heart tapers, and is continued backwards into a *superior abdominal artery* running in the middle line above the intestine and giving off numerous branches. From the point of origin of this vessel a *sternal artery* leaves the heart, gives a branch to the reproductive organs, and, running downwards on one side or other of the intestine, pierces the nerve-cord, beneath which it runs forwards, giving off numerous branches. Before running forwards, a large *inferior abdominal artery* arises from it, which takes a backward course under the nerve-cord.

The arteries branch repeatedly, and their finest ramifications end in the minute spaces, *lacunæ*, found in all parts of the tissues. These communicate with larger spaces, *sinuses*, that are placed around the various organs. The most important of these is the *sternal sinus*, running along the ventral surface. With it the others communicate. There are channels in the gills which communicate on the one hand with the sternal sinus, and on the other hand with *branchio-cardiac canals* which run up the sides of the thorax into the *pericardial sinus*.

Histology.—The most important point is the muscularity of the wall of the heart. Muscle-fibres are also present in the walls of the arteries. Both are lined by endothelium.

5. Respiratory Organs.—These are *gills* (branchiæ), adapted for breathing the oxygen dissolved in water. The gill-chamber on either side is covered over by the branchiostegite, and communicates with the exterior by a narrow slit running round the free edge of this. Particles of sand, &c., are prevented from entering by *coxopoditic setæ*, long tufts of hairs projecting from the basal joints of the third foot-jaws, forceps, and first three walking-legs. Each chamber contains 18 perfect, and 2 or 3 rudimentary gills. The ends of all converge upwards. Six of the perfect gills, *podobranchiæ* (Fig. 103, G, H, I, *ep*), are constituted by the lamellar epipodites of the second and third foot-jaws, forceps, and first three walking-legs, which bear a large number of delicate gill-filaments on their anterior and external surfaces. Eleven more, *arthrobranchiæ* (Fig. 103, N), are attached to the membranous junctions between the bases of the foregoing appendages and the body. Two (anterior and posterior) are placed on each of these junctions except the first, which possesses only one (anterior). These gills are plume-like, with a central stem bearing numerous gill-filaments. The remaining perfect gill, *pleurobranchia*, similar in structure to one of the arthrobranchiæ, is attached to the epimeron of the last thoracic segment. The two or three rudimentary gills are also pleurobranchiæ, and are attached to the epimera of the two or three preceding thoracic segments.

The stem of each gill is traversed by two channels, an *external* and an *internal.*

Histology.—The gills are covered with a very thin cuticle, continuous with the general exoskeleton. Underneath this lies a delicate epithelium. The connective-tissue forming the central part of the filaments is traversed by a network of blood-passages by which the external and internal channels of the stem are connected. The former of these are continuous with the sternal sinus, and the latter with the branchio-cardiac canals.

6. **Excretory Organs** (Fig. 105, B).—A pair of *renal organs,* the "green glands," are situated in the front of the head, one on either side of the circumœsophageal commissures (*see p.* 189). Each is a small green body (*gl*) round and flattened, from the upper surface of which proceeds the *renal duct.* This at once swells into an oval thin-walled bladder (*bl*), which opens (*st*) externally on the basal joint of the antenna (*comp. Fig.* 102).

Histology.—The green part is said to be made up of a single much-coiled tubule, lined by glandular epithelium.

7. **Reproductive Organs** (Fig. 105).—The sexes are distinct, and the external differences between them have already been mentioned.

(1.) In the **male** Crayfish (A) a single yellowish-white *male gonad* or *testis* underlies the pericardial sinus. It possesses two short anterior lobes (*t*), which broaden behind, and a longer and narrower posterior lobe (*t′*). A slender *male gonaduct* or *vas deferens* (*v.d*) arises on either side from the junction of the lobes. This enlarges considerably, and, after many convolutions, runs downwards to the *male genital pore* (*g.o*), situated on the proximal joint of the last pair of walking-legs.

The *spermatozoa,* as they pass out of the body, are aggregated into white threads.

The two first pairs of swimmerets are modified as *copulatory organs.*

(2.) The **female** (B) possesses a *female gonad* or *ovary* (*ov* and *ov'*), similar in shape to the testis, and occupying a similar position, but larger and broader. Its colour is reddish-brown, and its surface is raised up into rounded projections of various sizes, caused by the presence of ova. This is most obvious in the breeding season, when the ovary attains considerable dimensions. Within it is a cavity on either side into which *ovarian follicles* project, and from which, near the junction of the lobes, a short, wide *female gonaduct* or *oviduct* (*od*) proceeds. This opens on the basal joint of the second walking-leg (*g.o*). The *ova* are reddish-brown spheres, the size of medium shot.

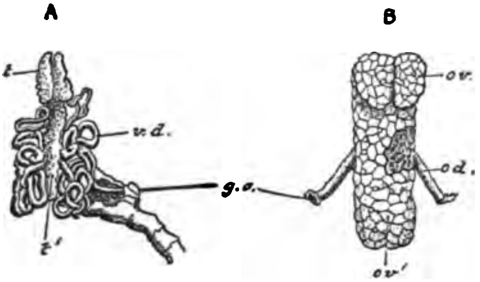

Fig. 105.—Reproductive Organs of Crayfish.—A, Male organs ; *t* and *t'*, anterior and posterior lobes of testis ; *v.d*, vas deferens ; *g.o*, style inserted into genital aperture. B, Female organs ; *ov* and *ov'*, anterior and posterior lobes of ovary ; *od*, oviduct ; *g.o*, genital opening. The ovary has been cut open on one side to expose its cavity.

Histology.—The vasa deferentia branch repeatedly within the testis, their finest branches ending in minute *lobules.* Each of these is formed by a small group of vesicles possessing an epithelial lining of *spermatospores.* Each of these divides, before the breeding-season, and gives rise to a number of *spermatoblasts*, which develop into *spermatozoa.* These are minute nucleated bodies, rounded and somewhat flattened, with a number of delicate, stiff processes, all curved in one direction, radiating from their edges. The epithelial lining of the vasa deferentia is glandular, and secretes a viscid fluid by which the spermatozoa are bound into threads.

The ova are enclosed in capsules, the *ovarian follicles,* which project into the cavities of the ovary. The wall of a follicle is formed by a structureless membrane, underneath which is a layer of simple epithelium. The large *ovum* possesses an external *vitelline membrane*, a *vitellus* containing a considerable quantity of yolk, and a *germinal vesicle* with numerous *germinal spots*. The walls of the oviduct are lined by glandular epithelium. The ripe ova burst out of their follicles, pass into the ovarian cavities, and thence by the oviducts to the exterior.

8. Muscular System.—The muscles of the internal organs have already been mentioned.

Locomotion is effected by swimming, walking, or climbing. The first results from alternate *flexion* (bending ventralwards), and *extension* (bending dorsalwards), of the abdomen. In accordance with this, two great *flexor muscles* arise from the roof of the sternal canal, and are inserted into the abdominal sterna, and two much smaller *extensor muscles* have their origin and insertion in the side-walls of the thorax and abdominal terga respectively. Movements of the walking-legs and forceps effect the other two modes of locomotion, and for these, as for all other movements of the appendages, special muscles are found, to which the exoskeleton affords origin and insertion. In many cases it is advantageous for a muscle to be attached to a small and definite area. This is managed by means of a fibrous *tendon*, to which the muscle-fibres are united.

Histology (*compare Chap. VIII.*)—Each muscle-fibre is invested by a delicate membranous sheath, the *sarcolemma*, and, owing to the regular alternation of dark and clear bands, is *transversely striated*. Hence the term "striped" or "striated" muscle. Longitudinal striations also occur, and along these the fibre can be split, after death, into *primitive fibrillæ*. Beneath the sarcolemma a number of longitudinal rows of *muscle-corpuscles* are arranged which resemble the nerve-corpuscles (Fig. 124) of nerve fibres, but are more regularly disposed. The fibres in the wall of the heart and alimentary canal are simpler in structure.

The *motor nerve-fibres* which are supplied to muscle come into very close relation with its fibres. The primitive-sheath becomes continuous with the sarcolemma, and the axis-cylinder passes into a granular, nucleated *end-plate*, resting upon the muscle substance.

9. Nervous System.—This is formed on the same type as that of the Earthworm. The *cerebral ganglion* is large, and situated in the front of the head between the origin of the eyestalks. It is probably formed of three pairs of ganglia (for segments 1-3) fused together. A very long *circumœsophageal commissure* runs down on either side of the gullet to join an elongated *infraœsophageal ganglion*, notched on either side, and representing the ganglion-pairs of segments 3-8 inclusive. Just before reaching this the two commissures are united together by a delicate transverse thread. The infraœsophageal ganglion is the first of the ventral cord, and, like the thoracic part of this, lies in the sternal canal. The rest of the cord consists of eleven well-marked bilobed ganglia connected by double commissures. The five free *thoracic ganglia* are placed at unequal distances, the posterior ones being rather near together. The commissures between the third and fourth diverge to allow the passage of the sternal artery. The six *abdominal ganglia* are placed at regular intervals just within the ventral wall of the abdomen. The last is somewhat larger than the others, and probably represents two pairs fused together.

The ganglia give off nerves to their own segments. Three pairs—*optic*, *antennulary*, and *antennary*—run from the cerebral ganglion to the eyestalks, antennules, and antennæ. The anterior part of the infraœsophageal ganglion supplies the mandibles, maxillæ, and first two pairs of foot-jaws. Its posterior part (the only partially fused ganglion of the third thoracic segment) supplies the third pair of foot-jaws, and behind it two pairs of interganglionic nerves run to the other parts of the segment. From most of the following ganglia two pairs of nerves proceed, the anterior of which supplies the corresponding pair of appendages. An interganglionic pair of nerves is found (in the majority of segments) behind the ganglion. The sixth abdominal ganglion supplies the last two segments.

The **sympathetic nervous system** consists of an *anterior visceral nerve* (formed by the union of three trunks, one running back from the cerebral ganglion, and one arising from each œsophageal commissure), which branches out on the stomach, and a *posterior visceral nerve* which runs forwards on the ventral surface of the intestine from the last abdominal ganglion. Several small *sympathetic ganglia* are present on the branches of the anterior visceral nerve.

Histology (*comp. Fig.* 124).—The *ganglion-cells*, which are here confined to the ganglia, possess the usual parts, and are surrounded by special nucleated sheaths. The *nerve-fibres* are invested by a firm *primitive-sheath*, in which small *nerve-corpuscles*, with large nuclei and scanty protoplasm, are imbedded at irregular intervals, and within the sheath is a clear structureless *axis-cylinder*.

10. **Sense Organs**—(1.) **Tactile Organs.**—The numerous setæ scattered over the body probably function as organs of *touch*. Bearing in mind the numerous setæ possessed by the elongated antennules and antennæ, these may well be called "feelers."

(2.) **Gustatory Organs.**—No special organs of *taste* have as yet been discovered.

(3.) **Olfactory Organs.**—Each joint of the antennulary exopodite bears below two tufts of flattened, spatula-shaped setæ, which probably serve as organs of *smell*, and are denominated *olfactory setæ*.

(4.) **Auditory Organs.**—The organs of hearing are two small *auditory sacs*, lodged one in the basal joint of each antennule, and opening by a hair-protected slit on its upper surface (Fig. 103, A, *au*). Each is somewhat pear-shaped, with a backwardly directed narrow end, into which an auditory nerve passes. The floor and posterior wall of the sac are raised internally into a ridge upon which numerous *auditory setæ* are arranged. These project into a gelatinous mass filling the cavity of the sac, in which are imbedded numerous foreign particles (sand, &c.), the *otoliths*. The auditory nerve breaks up in the wall of the sac, one of its fibres becoming continuous with the granular axis of each auditory seta.

In the ordinary and olfactory setæ a similar relation to nerve-fibres probably obtains.

(5.) **Optic Organs.**—*Sight* is effected by two *eyes*. Each of these is placed on a two-jointed stalk traversed by an *optic nerve*, which dilates at its extremity into a rounded *optic ganglion*. On the end of the stalk is an oval area, the *corneal lens*, where the cuticle is thin and uncalcified. Owing to underlying dark pigment it appears black. The corneal surface is divided into a large number of small facets, most of which are square, but others hexagonal. These *lenticules* are all in the same plane. Each corresponds to one of the elements which build up the deeper part of this so-called "compound" eye. These are the *visual pyramids*, slender, four- or six-sided bodies, whose bases are applied to the inner sides of the facets, while their slender apices abut against the optic ganglion. Each visual pyramid consists of a *sheath* (in which, especially at the two ends, dark pigment is present), and a transparent *visual rod* enclosed by this, which is made up of a *crystal-cone* externally, tapering and becoming continuous with an internal *striated spindle*.

PHYSIOLOGY.

1. **Nutrition.**—The Crayfish feeds upon various substances, vegetable and animal, which are seized by the chelate appendages and torn into small fragments. These are passed on by the first walking-legs to the third foot-jaws, by which, and the other mouth-appendages, they are still further reduced. All the jaws work from side to side, and not up and down, as in backboned animals. Mastication is completed by the gastric mill, the action of which is as follows:—The cardiac, pterocardiac, zygocardiac, and pyloric ossicles form an elastic-jointed frame, which, when not pulled upon, assumes a hexagonal form, with anterior and posterior sides formed by the first and last ossicles, and left and right angles bounded by the remainder. The lateral teeth project towards one another from the inside of these angles. The urocardiac and prepyloric ossicles, under the same conditions, make an acute angle with one another, and form an elastic-jointed connection between the cardiac and pyloric ossicles directed backwards and upwards.

By the contraction of the anterior and posterior gastric muscles the cardiac and pyloric ossicles are pulled away from each other, which involves—(1) the conversion of the hexagon into a rectangle, by which the lateral teeth approach; (2) the pulling out of the sharp fold made by the urocardiac and prepyloric ossicles, by which the median tooth passes downwards and forwards. Hence the three teeth meet together in the centre, and effectually chew anything that comes between them. The pyloric strainer prevents any large particles from passing on to the mid-gut. During the action of the gastric mill, probably, and certainly after reaching the mid-gut, the food is subjected to the action of the hepato-pancreatic fluid. This, by ferment action, converts starch into sugar, and proteids into peptones, while at the same time it emulsifies the fats.

The ridged and papillated lining of the intestine affords a large absorptive surface. Owing to the action of the muscle in the wall of the alimentary canal, the food is gradually passed backwards, as in the Earthworm, and the innutritious parts are ejected from the anus.

The digested parts of the food, which are either in solution or a state of very fine division, pass out of the digestive organs into the blood-system, by which they are distributed over the body. **Circulation** of the blood is effected by the rhythmical contraction of the heart, which acts as a central pump. The valvular ostia prevent the blood from passing out of the heart into the pericardial sinus (*see below*).

2. Destructive Metabolism.—(1.) **Respiration** is carried on by means of the gills. The scaphognathite continually moves backwards and forwards in the front of the gill-chamber, and by this means a continuous stream of fresh water passes over the gills, entering below and behind, and leaving in front. The movements of the appendages to which the podobranchiæ are attached must also produce currents which assist respiration, and the swimmerets may perhaps aid in the same way. The essential part of the process consists in the diffusion of carbon dioxide, brought as a waste-product from all parts of the body, out of the gill blood-spaces, and a diffusion into them of the oxygen dissolved in the surrounding water. The gills are placed in the course of the blood-current returning to the heart, this passing from the internal gill-channels to the branchio-cardiac canals, and thence into the pericardial sinus. The heart in its *diastole*, *i.e.*, when expanding, sucks in this purified blood through its ostia, and then undergoing *systole* (contracting) forces it into the arteries. From these it passes into venous spaces, and ultimately reaches the sternal sinus, loaded with carbon dioxide, and poor in oxygen. From the sternal sinus it enters the external gill-channels. The course taken by the blood, between its exit from the heart and re-entry of the same, is the *course of the circulation.*

In the young Crayfish water is regularly taken into, and expelled from, the intestine by the anus. This *anal respiration* may possibly also occur in the adult.

(2.) **Excretion.**—The renal organ has a rich blood-supply, and from this separates nitrogenous waste in the form of guanin ($C_5H_5N_5O$), and uric acid ($C_5H_4N_4O_3$), by means of its glandular epithelium. A considerable amount of water is also excreted.

3. **Reproduction.**—In the breeding season (autumn) the male, by means of the copulatory swimmerets, deposits sperm upon the posterior thoracic sterna of the female. The spermatozoa are bound together into thread-like masses by a secretion of the vas deferens. The eggs are probably fertilized after leaving the oviducts, but the spermatozoa are motionless, and the details of the process are unknown. Whether or no **polar cells** are formed previously, is also unknown. The walls of the oviducts secrete a glairy fluid, which quickly hardens. Each egg is enclosed in a sort of capsule formed by this secretion, and fixed by a filament of the same substance to one of the swimmerets. Some two hundred eggs are thus attached, and during the winter gradually develop, the movements of the swimmerets keeping them surrounded by pure water. It is evidently advantageous that the first pair of swimmerets in the female should be rudimentary or absent, as eggs attached to them would impede the swimming movements.

4. **Contractility.**—**Amœboid movement** is seen in the blood-corpuscles, but there are no instances of ciliary action. As in the Fluke and Worm, **muscular movements** are the most important, and these in most cases result from impulses conveyed to the muscles by motor nerve-fibres. The dark bands are the contractile part of the fibres.

The action of the gastric mill has already been described. The anterior and posterior gastric muscles, which work this, are termed "extrinsic" because they are not an integral part of the stomach, but merely attached to it. There are also "intrinsic" muscles in the wall of that organ, which, by contracting, diminish its cavity. Their action is opposed by several extrinsic muscles, not described above, which pull the walls outwards, and enlarge the cavity. By the alternate action of these, food is thoroughly mixed up, brought within the action of the teeth, and ultimately strained through the pylorus. Waves of contraction pass back along the intrinsic muscle in the walls of the mid-gut and intestine, by which peristaltic action their contents gradually travel backwards.

The *heart* does not contract in a wave-like manner, as do the "hearts" of the Earthworm, but all at once. The blood is consequently driven forwards and backwards into the arteries, whilst at the same time an equivalent quantity enters the pericardial sinus by the branchio-cardiac canals.

The *direction of movements* in the abdominal segments and appendages is mainly determined by the nature of the articulations. These are mostly "hinge-joints" permitting movement in one plane only. The abdominal segments are hinged laterally so as to allow of flexion and extension. The flexor and extensor muscles enable the animal to swim backwards, the effective movement being flexion, during which the tail-fin is spread out. Extension, during which the fin is folded up, is a comparatively feeble movement, as might be inferred from the relative smallness of the corresponding muscles, and merely serves to bring the tail into position for another stroke.

The joints of the walking-legs and forceps move in different planes, owing to the variety of ways in which the articulations are disposed. By a combination of movements these limbs can perform the most varied evolutions. The jaws work to and from the middle line; in other words, they are alternately *adducted* and *abducted.*

5. Irritability and Spontaneity.—The nerve-fibres are *afferent* and *efferent,* and the ganglion-cells are confined to the ganglia, which are consequently the **central organs.** Each ganglion has more especially to do with the segment it supplies, but can also work conjointly with others. An abdominal ganglion, for example, if cut off from communication with its neighbours, still causes regular movements in the corresponding swimmeret. These movements are undoubtedly caused by efferent nerve impulses from the ganglion, as they cease on its extirpation.

If the nerve-cord is cut at the end of the thorax, the abdominal ganglia, working *as a whole,* cause all the swimmerets to work regularly *together.* And by allowing more and more ganglia to remain, connected movements of increasing complexity are rendered possible. The addition of the cerebral ganglion, however, makes far more difference than the addition of any other. Without this the movements are for the most part irregular and lacking in purpose. The cerebral ganglion, in fact, controls the body at large.

The actions may be reflex or spontaneous. A **reflex action** starts with an external stimulus, by which one or more afferent fibres are affected. These carry impulses *to* the central organ, *from* which other impulses pass along efferent fibres to the parts they supply, causing them, if muscular, to contract. Suppose, for instance, the abdomen, when nervously isolated from the rest of the body, be irritated, say, by tapping, it will "flap vigorously." Here the tapping causes afferent fibres to carry impulses to the abdominal ganglia (central organs). These "reflect" the impulses into motor fibres, down which they pass to the flexor and extensor muscles, and cause these to contract.

Spontaneous actions are not directly dependent on external stimuli. A Crayfish from which the cerebral ganglion is removed exhibits constant movements, to all appearance "spontaneous," as above defined. They are, however, not *voluntary*, the effect of "will," spontaneous actions of this sort being probably the result of impulses passing from the cerebral ganglion. This, too, is the seat of consciousness and intelligence in so far as these exist.

The *sympathetic* nerves are concerned with the regulation of the movements of the alimentary canal. As small ganglia are developed upon their course in front, they acquire a certain independence.

The **special sensations** of touch, smell, hearing, and sight are present, and all result from the stimulation of certain "end-organs" by appropriate agents. These end-organs are closely connected with sensory nerve-fibres, along which afferent impulses pass to the cerebral ganglion, in the ganglion-cells of which they are converted into sensations—*how* is unknown.

The end-organs for **touch** are the ordinary setæ, upon which the usual stimuli act (*see p.* 155). Modified setæ, olfactory and auditory, play a similar part in **smell** and **hearing**, the respective stimuli being—contact of minute odoriferous particles detached from the body smelt, and sound-vibrations in the water. These last are intensified by the presence of the otoliths, which knock against the auditory setæ.

The striated spindles are probably the end-organs for **sight**, and the stimulus light-vibrations. The lenticules, crystalline cones, and spindles themselves serve as refractive agents. Each visual pyramid is only capable of perceiving rays which nearly or quite correspond with its axis, others being absorbed by the pigmented sheath. Hence, if the eye enables the animal to perceive the *form* of external objects, it must be by the *combined* action of the visual pyramids, which almost certainly do not act like so many simple eyes.

DEVELOPMENT.

1. **Early Stages** (Fig. 106).—**Segmentation** is *regular,* but *incomplete,* not affecting the whole ovum. This is owing to the presence of a considerable amount of nutritive food-yolk, which impedes division. At the end of segmentation (A) this forms a central mass (*v*), enveloped by the *blastoderm,* a thin investment made up of a single layer of small cells (*bl*), which become thickened over a small oval area, the *germinal disc.* The posterior part of this is **invaginated** (B) to form a small pouch (*m.g*) sunk in the food-yolk. The **gastrula** stage is now reached, corresponding to that of the Earthworm. The walls of the pouch form the **hypoblast,** while its cavity is the *archenteron,* and its wide mouth the *blastopore* (*bp*). This last narrows, and eventually closes. The remaining cells of the blastoderm constitute the **epiblast.** Owing to the presence of food-yolk, which the epi-

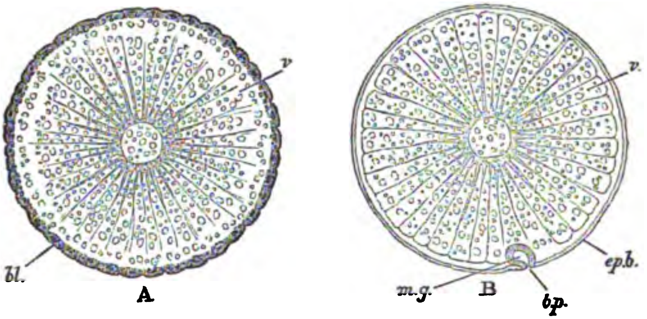

Fig. 106.—SEGMENTED OVUM AND GASTRULA OF CRAYFISH (from *Haddon,* after *Reichenbach* and *Huxley*).—A, Segmented ovum ; *bl,* blastoderm ; *v,* yolk. B, Gastrula ; *ep.b,* epiblast ; *m.g,* archenteron (which becomes the mid-gut), bounded by hypoblast, shaded darkly ; *bp,* blastopore.

blast envelops, the two layers are very unequal in extent. The **mesoblast** is formed by a solid mass of cells arising in front of the archenteron, and derived from its wall.

2. General Growth.—The germinal disc is the first trace of the ventral surface of the embryo. From its hind end the abdomen grows out as a small knob, and on its front end and sides little elevations appear, the rudiments of the eyes, labrum, and appendages of the head and thorax. The swollen part containing food-yolk corresponds to the dorsal region of these last. It becomes smaller as its contents are used up in the processes of growth.

The young Crayfish are hatched at or near the commencement of summer. They closely resemble the adult in form, but the first and last abdominal appendages are wanting, and the ends of the forceps are sharply hooked, thus serving as a means of attachment to the "egg-glue" with which the swimmerets are more or less covered.

Owing to the firm exoskeleton, growth cannot take place as in soft-bodied animals, and the adult size is only reached after a series of *moults* or *ecdyses*, by which the cuticular parts (including the endophragmal system and the cuticular linings of the fore- and hind-guts) are thrown off, fresh being subsequently formed. As many as eight ecdyses take place in the first year, five in the second, and after this one or two per annum.

3. Fate of the Germinal Layers.—(1.) The **epiblast** gives rise to the epidermis, with the exoskeleton and its various types of setæ. The epithelium and cuticular structures of the fore- and hind-guts are also derived from this layer. They both arise as deep pits which become connected with the archenteron to form a continuous alimentary canal. The nervous system arises as epiblastic thickenings, which come to lie within the body-wall. Minute depressions on the exterior become the auditory sacs. The lenticules and crystalline cones of the eyes are formed by thickenings of the superficial epiblast, which fuse with outgrowths from the cerebral ganglion that develop into the striated spindles.

(2.) The **hypoblast** is converted into the epithelium of the mid-gut, which the archenteron becomes. From this a hepato-pancreas grows out on either side.

(3.) The **mesoblast** does not divide into regular mesoblastic somites, as in the Earthworm. Irregular spaces are formed in it which become the venous sinuses. The circulatory and respi-

TABLE OF CRAYFISH SEGMENTS.

	No. of Segment.	Skeleton.	Appendages.	Apertures.	Gills.			Ganglia.	Sense-Organs.
					Pod.	Arth.	Pleu.		
Head.	I.	Carapace.	Eye-stalks	...	...	...	...	Cerebral (Gang. 1)	Optic
	II.		Antennules	Auditory	...	...	...		Tactile Olfactory Auditory
	III.		Antennæ	Excretory	...	...	...		Tactile
	IV.		Mandibles	... Mouth	...	...	...	Infra-œsophageal (Gang. 2)	The appendages of segments II. and III. subserve the function of touch more particularly, but tactile organs are not confined to them, being scattered over the whole body.
	V.		Mx. 1	...	...	...	...		
	VI.		Mx. 2	...	Scaphog	..	...		
Thorax.	VII.		Mxpd. 1	...	Epipod	...	...		
	VIII.		Mxpd. 2	...	1	1	...		
	IX.		Mxpd. 3	...	1	2	...		
	X.		Forceps	...	1	2	...	Gang. 3	
	XI.		Leg 1 } Chelate	...	1	2	[*r*]	Gang. 4	
	XII.		Leg 2	Female genital	1	2	*r*	Gang. 5	
	XIII.		Leg 3	...	1	2	*r*	Gang. 6	
	XIV.		Leg 4	Male genital	...	...	1	Gang. 7	
Abdomen.	XV.	Free.	Male. Female modified Swt. 1 0 or *r*	...	...	...	...	Gang. 8	
	XVI.		Swt. 2 normal	...	...	...	...	Gang. 9	
	XVII.		Swmt. 3	...	...	...	...	Gang. 10	
	XVIII.		Swmt. 4	...	...	...	...	Gang. 11	
	XIX.		Swmt. 5	...	...	...	...	Gang. 12	
	XX.		Swmt. 6 (very large)	...	...	...	...	Gang. 13	
	XXI.		0	Anus	...	...	...		

r = rudiment; [ ] signify present or absent.

ratory organs (except the epithelium and cuticle), the excretory (?), and reproductive organs, together with the muscular system and the connective-tissue uniting the various parts, all arise from this layer.

CHAPTER V.—MOLLUSCA.

§ 7. ANODONTA and UNIO (Fresh Water Mussels).

These are found in considerable numbers in the mud at the bottom of many ponds, streams, and canals, in this amongst other countries. Mature specimens may be as much as five or six inches long.

MORPHOLOGY.

1. **External Characters.**—The body is bilaterally symmetrical, and entirely enclosed in a calcareous *shell*, which is *bivalve* —*i.e.*, made up of two pieces or *valves*. These are placed on the sides of the animal, and are consequently right and left. They are connected together dorsally by the *ligament*, an uncalcified band of horny elastic fibres, which in the closed shell are on the stretch. In dead examples, there is nothing to keep the valves closed, and they consequently "gape," owing to the elasticity of the ligament. Each valve is oval with a rounded anterior and a more pointed posterior end. On the dorsal margin of the valve, the *umbo* or oldest part is situated not far from the anterior end. Around the umbo *lines of growth* are concentrically disposed, which mark successive additions made during the life of the animal. The outside is olive green in colour, owing to the *periostracum*, a thin horny membrane. The shell is lined by a *pearly layer*, and this is marked by a number of *muscular impressions*. Near the anterior end, there is an oval *anterior adductor impression*, and near the posterior end a similar but larger *posterior adductor impression*. The two are connected by a *pallial line* running parallel to the ventral edge of the shell. Immediately behind the anterior adductor

impression is a much smaller *anterior retractor impression*, behind which again is a small *protractor impression.* Just in front and above the posterior adductor impression, there is a small *posterior retractor impression.* From the various places above mentioned lines of *shifting* converge towards the umbo.

In *Unio* the valves are connected at the hinge-line by small projections, *teeth*, which fit into corresponding *sockets.*

In removing the animal from its shell the various muscles attached to the impressions are cut through. They have corresponding names. The *adductor muscles* (Fig. 107, V.S and H.S) are broad bands of fibres which run transversely across from one valve to the other, and by their contraction keep the shell closed.

Each shell is lined by a flap of skin, the right or left lobe of the **mantle.** These lobes have thickened edges which are attached to the shell along the pallial line (Fig. 107, Mt). They are continuous dorsally with the wall of the body, are

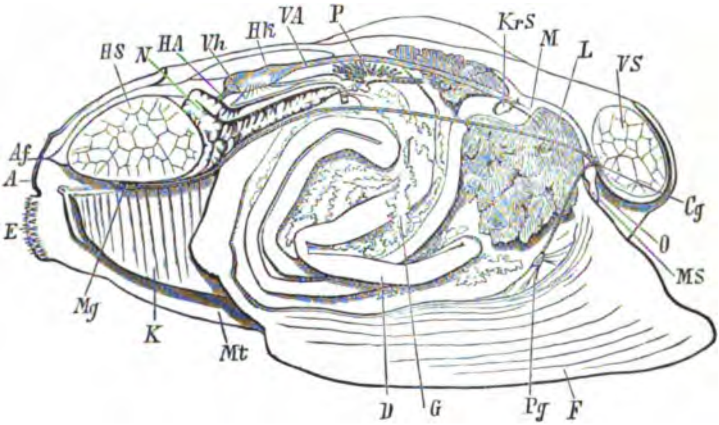

Fig. 107.—General Dissection of Unio (from *Claus*, after *Grobben*).—V.S and H.S, anterior and posterior adductors; M.S, labial palp; F, foot; Mt, mantle; K, gills; C.g, cerebral ganglion; P.g, pedal ganglion; M.g, olfactory ganglion; O, mouth; M, stomach; L, hepato-pancreas; Kr.S, crystalline style; D, intestine; Af, anus; G, genital gland; A, exhalent aperture; E, inhalent aperture; N, nephridium; Vh, auricle; Hk, ventricle; V.A, anterior aorta; H.A, posterior aorta.

fused together above and behind the posterior adductor (H.S), and immediately beyond this are closely apposed to bound two oval openings. These are—a smaller *exhalent* or *cloacal aperture* (A) above, and a larger *inhalent aperture* (E) below, the edges of which are fringed with short tentacles. In the living state the Mussel often comes to the surface of the mud, in which it is obliquely imbedded, and its posterior end projects, so that water can pass in at the inhalent and out at the exhalent aperture. The mantle lobes enclose between them a large space, the *mantle-cavity*, which is divided into two parts, a large *branchial chamber* below, and a small *supra-branchial chamber* above. It must not be supposed that the mantle-lobes are fused posteriorly to bound the inhalent and exhalent apertures, or ventrally to bound the branchial chamber. If the animal is placed on its back the lobes can be turned back on either side without cutting anything, as in Fig. 108, where by this means the contents of the branchial chamber are exposed. In this figure the smooth sides of the exhalent aperture have been separated, and are seen just above A, on either side of which letter are the fringed right and left sides of the inhalent aperture. A large oval *visceral mass* (mesosoma), compressed from side to side, hangs down into the branchial cavity, but there is no distinct head. The lower edge of the visceral mass is produced into a yellow ploughshare-shaped muscular expansion, which projects forwards (Fig. 107, F; and Fig. 108, P). This *foot* can be protruded from the shell, and serves as a locomotor organ. On either side of the visceral mass is a *gill* (*ctenidium*), made up of two elongated plates (Figs. 107 and 108, K). These extend behind the visceral mass below the posterior adductor, and in this region the gills of opposite sides are united together. In Fig. 108 this union has been cut through in order to expose part of the supra-branchial chamber. At the anterior end of the visceral mass, and just beneath the anterior adductor, is a transversely elongated opening, the *mouth* (O), and on either side of this are two triangular plates, the *labial palps* (Fig. 108, Se), which are united together at their bases to form ridge-like anterior and posterior lips. The exhalent aperture leads into a *cloacal chamber*, which is the posterior part of the supra-branchial chamber, and is floored by the union of the gills. The last part of the intestine or *rectum*, upon which is placed the small *anus* (Fig. 107, Af, and Fig. 108, A), runs dorsal to the posterior adductor, and projects into this chamber. Upon either side of the visceral mass, near the attachment of the gills, a small male or female *genital opening* is placed (Fig. 108, Oe′), and close to this is a rather larger *excretory* or *renal opening* (Oe″).

2. Skin.—The most important part of this is the **mantle**, which forms a sort of flap drawn out on either side. The *shell*, which is secreted by this, consists of three layers, a thin outer olive-green *periostracum*, an inner laminated *pearly layer*, and between the two a thick, compact *prismatic layer*, made up of polygonal prisms packed closely together, and arranged obliquely to the surface. The shell, like that of Astacus, is a cuticular structure, very much thickened, and hardened by the deposition of carbonate of lime. The external surface of the body and mantle can add to the pearly-layer, but the other two can only be increased by the thickened edges of the mantle, and these form the successive increments indicated by the lines of growth.

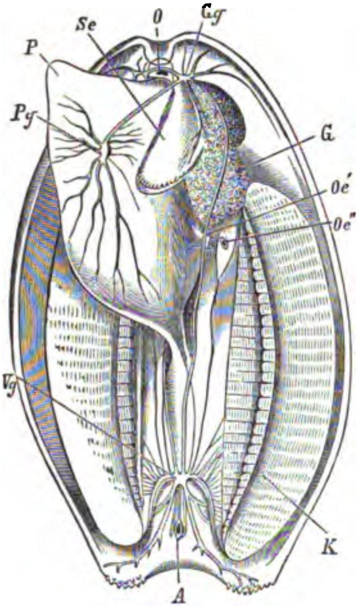

Fig. 108.—Nervous System of Anodonta (from *Claus* after *Keber*).—O, Mouth; A, anus; K, gills; P, foot; Se, labial palp; Gg, cerebral ganglion; Pg, pedal ganglion; Vg, olfactory ganglion; G, genital gland; Oe′, opening of ditto; Oe″, opening of excretory organ.

Pearls are formed by the deposition of matter similar to that making up the pearly layer around grains of sand, &c., that get into the shell. The pearl-fisheries of Britain were once famous, the pearls being obtained from a species of Unio. In China, small metal images of Buddha are placed within the shells of fresh-water mussels, and thus receive a pearly coating.

Histology.—The *mantle* is covered externally and internally by a layer of simple columnar epithelium, which on the outer side contains many glandular cells, and on the inside is ciliated. The substance of the mantle between these layers of epithelium is made up of connective-tissue, traversed by blood-channels.

The skin covering the visceral mass and foot is very glandular and closely connected with underlying layers of muscle. The labial palps are, like the inside of the mantle, covered by ciliated epithelium.

3. Digestive Organs (Fig. 107).—The *mouth* (O), on either side of which are the transversely striated labial palps (MS), leads into a very short *œsophagus*, which runs almost directly upwards, just behind the anterior adductor, and passes into a rather more dilated part, the *stomach* (M).

In Unio a transparent rod, the *crystalline style*, is contained in a pouch of the stomach, into which organ its end projects (Kr.S). From the posterior end of the stomach a narrow thin-walled *intestine* arises (D), which coils about (mostly in the median vertical plane) within the visceral mass, where it is closely surrounded by the genital gland (G), (both being imbedded in connective-tissue). It finally curves upwards and runs back near the dorsal surface of the body, passing as the *rectum* through the ventricle of the heart, and over the posterior adductor to terminate in the anus. A longitudinal *intestinal valve*, resembling the typhlosole of the Earthworm, is present in the last third of the intestine. Surrounding the stomach and adjoining parts of the œsophagus and intestine is a *hepato-pancreas* (L), made up of numerous brown branched tubules, and opening into the stomach by a short duct on either side.

Histology.—The alimentary canal is lined throughout by simple columnar epithelium, which is partly ciliated, partly glandular. External to this are muscular layers. The tubules of which the hepato-pancreas is composed are lined by glandular epithelium, made up of cuboidal cells with brown granular contents. By the successive unions of these tubules, the ducts are finally formed.

4. Circulatory Organs (Fig. 107).—A **blood system** alone is present, containing *blood* like that of *Astacus* (*p.* 184). A *pericardial cavity* with thin walls is placed on the dorsal side of the body.* The *heart*, which is contained within this, consists of a central oval muscular *ventricle* (Hk), into which a thin-walled

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* The pericardial cavity does *not* contain blood.

auricle (Vh) opens on either side. The auricles are funnel-shaped, with the narrow end attached to the ventricle, the broad end to the ventro-lateral wall of the pericardial cavity. An *auriculo-ventricular valve* is placed at the point of union of either auricle with the ventricle. It is made up of two small flaps, which permit blood to pass into but not out of the ventricle.

The ventricle (through which the rectum runs) gives off two arteries, an *anterior aorta* in front (VA) running forwards above the rectum, and a *posterior aorta* behind (HA), running backwards below the rectum. The anterior aorta divides into branches, which supply the greater part of the alimentary canal, the foot, the anterior adductors, and adjacent parts; while the posterior aorta supplies the hinder part of the rectum, the posterior adductors, and the greater part of the mantle. The ultimate branches of these arteries end in lacunæ. From these in the foot and organs of the visceral mass, the blood is returned by venous sinuses to the *vena cava,* a longitudinal vessel lying in the middle line immediately below the floor of the pericardial chamber. The blood passes from the vena cava into the nephridium on either side, where it enters a close network of channels. From this network vessels run to the gills, opening on either side into an *afferent branchial vein,* which runs along the junction of the outer and inner gill-plate. Numerous branches pass into the gill-substance from this vein. The blood is returned to each auricle by an *efferent branchial vein,* which takes a course along the attachment of the outer lamella of the outer gill-plate on that side. Efferent veins from the mantle-lobes also enter the efferent branchial veins.

Three small pits are found in the middle line on the ventral edge of the foot. These are regarded by some zoologists (but without sufficient evidence) as pores, by which the vascular system communicates with the exterior.

Histology.—The heart and arteries are lined by *endothelium,* and their walls contain an abundance of muscular fibres.

5. Respiratory Organs.—These consist of a *gill* (*ctenidium*) on either side (K), composed of an inner and an outer gill-plate. Each plate is again made up of an outer and inner *lamella* (in Fig. 108, K, is placed on the left inner gill-plate) united together ventrally. The *outer* lamella of the outer gill-plate is attached by its dorsal edge to the inner side of the mantle, close to where it joins the body-wall. The *inner* lamella of the outer gill is united above with the outer lamella of the inner gill, and the common union of the two (gill-axis) is attached above to the wall of the body. The *inner* lamella of the inner gill-plate is attached anteriorly to the body-wall, is then free for a short distance, and behind the visceral mass unites with its fellow in the middle line to form the floor of the cloacal chamber. The gill-lamellæ are vertically striated, and between the striations numerous minute apertures are present. These place the branchial cavity in communication with a space present in the interior of each plate, which is divided into a number of vertical *water-tubes* by the union of the two lamellæ along a corresponding number of narrow vertical strips. The visceral mass divides the anterior part of the *supra-branchial chamber* into right and left halves. Each of these, owing to the dorsal attachment of the gill-axis, is again subdivided into two. There are, therefore, four channels above the gill-plates in this region, into which the four sets of water-tubes open. Behind the visceral mass the two inner channels coalesce with one another, and finally, in the cloacal region, the supra-branchial chamber is undivided.

In Fig. 108 the cohering inner plates have been separated so as to expose part of the supra-branchial chamber.

The gills of Anodon are unusually complicated. They appear to have arisen in the following way:—From the gill-axis on either side two longitudinal rows of filaments grew out. The ends of the outer row turned sharply outwards and upwards; those of the inner row inwards and upwards. Thus in cross-section a W-shaped outline would be seen. These filaments then fused into two folded lamellæ, numerous apertures being left, however. The descending and ascending halves of each lamella then became connected to form a gill-plate. Union of the plates with one another and with surrounding parts increased the complexity, and brought about the distinction between branchial and supra-branchial chambers.

Histology.—Each gill is covered externally by a single layer of ciliated epithelium, with which the water tubes are also lined. The external ridges (representing filaments), which appear to the naked eye as vertical striæ, are supported by slender horny rods, two of which run vertically within each ridge. Beneath the epithelium the gills are composed of loose connective-tissue, everywhere permeated by blood-containing lacunæ. The partitions, at once uniting the lamellæ and separating the water-tubes, are traversed by more definite blood-channels.

6. Excretory Organs (Fig. 107, N).—A pair of renal organs or *nephridia* are present (organs of Bojanus). Each of these is essentially a tube folded upon itself, and communicating on the one hand with the pericardial cavity, and on the other with the exterior by the renal opening noted above. The tube is divided into a dilated glandular part, the lining of which is raised into numerous ridges, and a narrower non-glandular part. The vena cava lies between the non-glandular parts of the two nephridia, which open in front by the renal openings, and behind communicate with the glandular parts which underlie them. (Close to N.) The glandular part is broadest behind, where it abuts upon the posterior adductor, and narrows in front where it opens into the floor of the pericardium (*see Fig.*)

Histology.—The glandular parts of the nephridia are lined by glandular epithelium, the cells of which are granular, and often contain concretions.

7. Reproductive Organs.—The sexes are distinct, and the female is somewhat thicker from side to side. The *gonads* (*testes* or *ovaries*, as the case may be) are yellowish, very much-branched structures, surrounding the coils of the intestine in the visceral mass (Fig. 107, G). They are made up of blind tubules, from which ducts pass on either side, uniting together into a *male* or *female gonaduct*, just before opening to the exterior by the genital aperture (Fig. 108, Oe′).

Histology.—The tubules of the gonads are lined by germinal epithelium. These in the male produce large numbers of *spermatozoa*, each of which possesses a cylindrical head and motile filiform tail. In the female *ova* are developed, each of which is covered by a vitelline membrane, which at one point, the *micropyle*, is incomplete. The *vitellus*, which contains a moderate amount of food-yolk, is separated when ripe by albuminous fluid from the vitelline membrane. It contains a large *germinal vesicle* with a *germinal spot*. Each ovum while still in the ovary is contained in a *follicle*, to the wall of which it is attached by a protoplasmic stalk passing through the micropyle.

8. Muscular System.—The skin is intimately connected with muscle underlying it, and the walls of the alimentary canal, heart, and arteries are also muscular. The *posterior* and *anterior adductor* muscles have already been mentioned. The foot is almost entirely made up of muscle, and from it slender *protractor*, *anterior retractor*, and *posterior retractor* muscles arise, which are inserted into the corresponding muscular impressions.

Histology.—The muscles are composed of fusiform muscle-cells, exhibiting somewhat indefinite transverse striations, which do not seem to represent those found in the Crayfish.

9. Nervous System.—This is mainly constituted by three pairs of ganglia connected together by commissures. On either side of the mouth, just beneath the skin, a *cerebral ganglion* (more properly *cerebro-pleuro-visceral*) is situated. These two ganglia are connected together by a short commissure above the mouth (Fig. 107, Cg, and Fig. 108, Gg). A pair of *pedal ganglia* (Pg) lie close together at the junction of the foot and the visceral mass, resting upon the muscle of the former nearer its anterior than its posterior end. Each of these ganglia is connected by a commissure with the corresponding cerebral ganglion. The third pair of ganglia is the *olfactory* or *osphradial* (*parieto-splanchnic*), placed close together on the under surface of the posterior adductor (Fig. 107, Mg, and Fig. 108, Vg). A very long commissure runs back from each cerebral ganglion to the olfactory of the same side, to reach which it first traverses the hepato-pancreas, and then takes a course along the inner side of the nephridium. The cerebral ganglia supply the labial palps, anterior adductor, and other parts of the same region (also the posterior adductors), while nerves are given off from the pedal ganglia to the muscular tissue of the foot, and from the olfactory ganglia to the mantle, gills, osphradia, and posterior adductor. (*Compare* Figs. 107 and 108.)

Histology.—As usual, *ganglion-cells* and *nerve-fibres* are the essential parts of the nervous system, the former being entirely confined to the ganglia, as in Astacus.

10. Sense Organs.—(1.) **Tactile Organs.**—The labial palps act as feelers, and their epithelium comes into close relation with fibres from the cerebral ganglia. The tentacles surrounding the inhalent aperture are well supplied with fibres from the olfactory ganglia, and appear to be especially sensitive.

(2.) **Gustatory Organs.**—The labial palps (?) possibly subserve the function of taste.

(3.) **Olfactory Organs.**—The patch of epithelium, *osphradium*, covering each olfactory ganglion, probably has to do with smell. It is composed of elongated sense-cells.

(4.) **Auditory Organs.**—A minute vesicle, the *otocyst*, is placed on the end of an auditory nerve given off from the posterior end of each pedal ganglion. It is lined by elongated auditory cells, possessing auditory hairs, and contains a clear fluid, within which a calcareous particle, the *otolith*, is suspended.

(5.) **Optic Organs** are absent.

PHYSIOLOGY.

1. **Nutrition.**—The ciliated epithelium, lining the mantle-lobes and covering the gills and labial palps, sets up currents in the mantle-cavity, and causes water to enter the branchial chamber by the inhalent orifice. Some of this is conducted along the labial palps to the mouth, into which the small organisms it contains are carried. These constitute the *food*, and by the contraction of the muscular walls of the alimentary canal gradually pass backwards within it. The hepato-pancreatic fluid probably acts in the same way as that of the Crayfish (*p.* 192). The length of the intestine increases the surface for absorption, and this is augmented, as in the Earthworm, by the typhlosole. The digested parts of the food pass into the blood-system through the intestinal walls, while the refuse is ejected at the anus, and is carried out of the cloacal chamber by the currents which flow from the exhalent aperture as a result of ciliary action.

Circulation.—The *heart* receives pure blood from the gills and mantle lobes, which passes into the auricles, and thence into the ventricle. The former contract together, filling the ventricle, which then also contracts in a wave-like manner, and forces the blood through the arteries to the body at large. It is, therefore, as in the Crayfish, a *systemic* heart. From the smallest arterial branches the blood passes into the lacunæ, and thence into venous channels, which are arranged as above described. The result is that the blood from the visceral mass and foot is purified in the nephridia, and then in the gills, before reaching the auricles, while the blood from the mantle-lobes is oxygenated there, and returned to the auricles without passing through the nephridia or gills.

2. **Destructive Metabolism.**—(1.) **Respiration.**—This is partly effected by the inner surface of the mantle-lobes, but mainly by the gills. Water entering by the inhalent aperture passes into the water-tubes of the gills, through the numerous small apertures

in the lamellæ. It then runs upwards into the supra-branchial chamber, and backwards through the exhalent aperture to the exterior. All the currents are the result of ciliary action. The essential part of the process is the same as in the Crayfish (*p.* 192).

(2.) **Excretion.**—The nephridia act in exactly the same way as the renal organs of the Crayfish (*p.* 193), and guanin ($C_5H_5N_5O$), uric acid ($C_5H_4N_4O_3$), and urea (CH_4N_2O), have been detected in the concretions they contain.

3. **Reproduction.**—The ova of the female pass from the genital openings into the water-tubes of the outer gill-plates, where they are fertilized by spermatozoa, which at the same time pass out from the exhalent aperture of the male. The entry of the spermatozoon appears to take place by the micropyle. Fertilization is preceded by the formation of *polar cells.* The breeding season is in the summer.

4. **Contractility.**—**Amœboid** movement is exemplified as usual by the blood-corpuscles. **Ciliary action** is abundantly shown in the epithelium of the gills, &c. It is here of great importance, as the entry of food- and oxygen-bearing currents is thus effected, as well as the exit of other currents carrying away waste-products, and the refuse of the food.

Muscular movements are principally shown (apart from the alimentary canal and circulatory organs) in the contractions of the foot, which serves as an organ of locomotion, causing the animal to progress backwards in the mud by a sort of shoving action. The retractor muscles by their contraction draw it back, and the protractors pull it forwards.

5. **Irritability and Spontaneity.**—*Compare p.* 155.

DEVELOPMENT.

This takes place up to a certain point within the water-tubes of the outer gills.

1. **Early Stages.—Segmentation.**—The fertilized ovum is at first uniformly granular, but soon elongates and becomes clear at one end, from which a small cell is pinched off. This process is continued until a *blastosphere* is formed, containing a segmentation-cavity. The greater part of the wall of the sphere is composed

of small clear cells, but at one point there is a larger granular cell.

Invagination.—The granular cell divides into a number of others, and this end of the egg is pushed inwards to form a *gastrula.* This is a double-walled sac, the outer wall of which is the **epiblast**, formed by the small clear cells, and the inner wall the **hypoblast**, formed by the granular cells. The two are widely separated by the remains of the segmentation cavity. The *archenteron* opens to the exterior by a large *blastopore.*

The **mesoblast** partly originates from two large cells, budded off into the blastosphere from the large granular cell before invagination, and partly from smaller cells budded off afterwards from the edges of the blastopore. It ultimately forms a continuous layer between the other two.

2. General Growth.—The most important point to be noted is the development of the shell. This first commences as a single saddle-shaped plate on the dorsal surface. As the mantle-lobes are formed, this is divided into the two valves, which remain connected by the ligament. This must be regarded as an uncalcified part of the shell. Each valve is triangular, and its lower pointed end is bent inwards into a sharp spine. In the hinder part of the body a pit is formed, the *byssus gland*, which secretes a long filament or *byssus.*

Many shell-fish, *e.g.*, the salt-water Mussel, are attached during life to surrounding objects by threads forming the *byssus.*

The embryo now passes out of the gill of the parent, being ejected from a small opening bounded by the coalesced mantle-lobes, and situated some distance above the exhalent aperture. The young mussel is very unlike the adult. It was formerly thought to be a distinct mollusc, and named *Glochidium.* This, however, was afterwards found to be only a *larva, i.e.,* a free-living embryo, very dissimilar to the mature form, and undergoing a series of changes known collectively as a **metamorphosis** before becoming adult.

The Glochidium has special larval sense organs, by which it is enabled to detect the presence of fish. It swims by flapping the valves of the shell. The long byssus trails behind, and effects attachment to the skin of a fish. The sharp spines on the valves then give a firmer hold. In this position it is covered over by an outgrowth from the epidermis of the fish, and undergoes metamorphosis. The byssus and larval sense organs are lost, the foot, gills, and internal organs (except the reproductive) are gradually developed. The host is then left.

3. Fate of the Germinal Layers.

(1.) **Epiblast.**—This gives rise to the epidermis with its shell, and to the epithelium lining the otocysts, which first commence as pits on the external surface, and are gradually closed and separated off. The nervous system also probably arises from this layer.

(2.) **Hypoblast.**—This originates the epithelial lining of the alimentary canal and the hepato-pancreas.

(3.) **Mesoblast.**—From this the remaining structures are developed. (*Compare p.* 197.)

§ 8. HELIX (The Snail).

The two species of Helix most available in Britain for dissection are *Helix aspersa*, the common snail, and *Helix pomatia*, the Roman snail. *H. pomatia* is characterised by its much larger size, and lighter colour. In the essential features of its organization, however, it differs but little from *H. aspersa*, which, as the commoner kind, will be described here.

MORPHOLOGY.

1. External Characters.—The most striking feature is the possession of a *shell*, into which the animal can entirely withdraw itself. It consists of one piece only; in other words, it is *univalve*. If a hollow cone with a very small angle is thought of as wound round and round into a right-handed spiral with closely adherent coils, a good notion will be formed of its structure. By the juxtaposition of the inner edges of the coils or *whorls*, a hollow pillar, the *columella*, is produced, which forms the axis of the spiral, and opens to the exterior below. The opening of the shell, *mouth*, or *peristome*, has a prominent smooth rim. The blind end is termed the *apex*.

During winter the snail hybernates, when the aperture of the shell is closed by means of a thick calcareous plate, the *epiphragm* or *hybernaculum.* When the animal is fully expanded, the part of the body protruding from the shell is bilaterally symmetrical, while a dorsal portion, the *visceral hump,* contained within the shell is, like it, spirally coiled. This part of the body is attached by the *spindle-muscle* to the columella, and is covered by a thin membrane, the *mantle,* which ends anteriorly in a thickened edge, the *collar.* The rest of the body is for the most part covered with corrugated skin, but there is an exception to this in the under side of the *foot,* an elongated muscular expansion running along the ventral side of the body, tapering behind to a point, and in front ending just below the mouth. Upon the smooth surface of this expansion the animal crawls.

Placed in front is the *head* or *prosoma,* the rest of the body being called the *mesosoma.* The head bears two pairs of *tentacles* or *feelers,* which are hollow, and can be retracted into the body, as the finger of a glove can be turned into the glove's interior. Each of the posterior, longer pair, the *optic tentacles,* bears a small black dot, the *eye,* at its tip. The anterior shorter pair are the *olfactory tentacles.* In the front of the head is the *mouth,* guarded by a circular and two lateral *lips.* Below the mouth there is a small pore, the opening of the *pedal gland.* Not far below the right optic tentacle the rounded *genital opening* is situated. In the thickened anterior edge of the mantle, on the right side, there is a deep depression, into the left side of which the large valvular *respiratory aperture* opens, and on the right of this a smaller *anus.*

2. Skin.—The surface of the skin varies as above mentioned. The mantle is so thin and transparent that many of the internal organs, nephridium, hepato-pancreas, &c., can be seen through it. This part of the skin, as in the Mussel, is glandular, and secretes the shell. The slimy nature of the body is due to the glandularity of the rest of the skin.

Histology.—An epidermis made up of a single layer of columnar cells, can be distinguished from a connective-tissue *dermis,* closely united with subjacent muscular tissue.

The *shell,* as in the Mussel, consists of three layers. There is a thin external chitinous *periostracum,* which is pigmented, and gives colour to the shell. Below this is a dense *prismatic layer,* and internally a thinner *pearly layer,* composed of numerous laminæ, and with a smooth and polished internal surface. The last layer can be secreted by all parts of the mantle, but the two others can only be formed by the collar, which, as the animal grows, adds successive increments to the mouth of the shell, the boundaries between which are indicated by *lines of growth.*

3. Digestive Organs (Figs. 109, 110).—The *mouth* (*m*, Fig. 109; O, Fig. 110) leads into a large mouth-cavity, contained in an oval muscular *buccal mass* (*b.m*). Immediately within the circular lips, dorsally, is a crescentic, horny, toothed structure, the *upper jaw* (Fig. 110, Kf). But the most important organ connected with the mouth is the *odontophore.* This consists of an elevation rising up like a tongue from the floor of the mouth, on which a horny ribbon, the *radula* (*Rd*) is spread out from back to

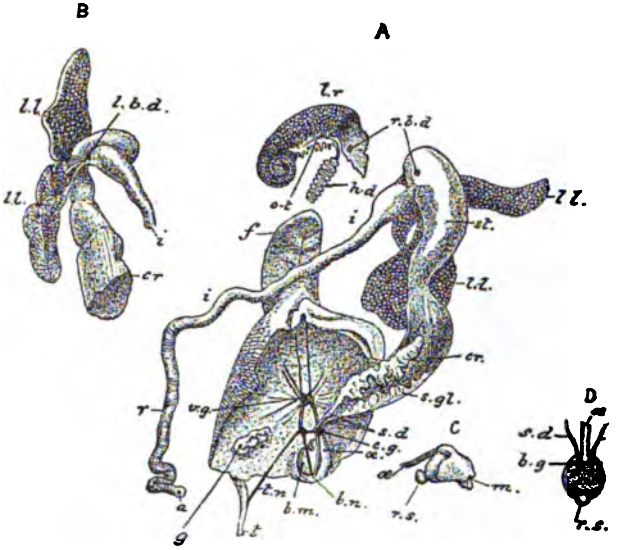

Fig. 109.—Digestive Organs and Nervous System of Snail.—A, General view; B, left side of stomach, &c.; C and D, side and hind views of buccal mass; *a*, anus; *b.g*, buccal ganglion; *b.m*, buccal mass; *b.n*, buccal nerve; *c.g*, cerebral ganglion; *cr*, crop; *g*, place from which genitals were cut away; *h.d*, hermaphrodite duct; *i*, intestine; *l.l*, left lobe of hepato-pancreas; *l.b.d*, left hepato-pancreatic duct; *l.r*, right lobe of hepato-pancreas detached from stomach; *r*, rectum; *s.d*, salivary duct; *st*, stomach; *t*, tentacles; *t.n*, tentacular nerve; *r.s*, radular sac; *v.g*, ventral ganglionic mass; *o.t*, ovo-testis; *r.b.d*, right hepato-pancreatic duct.

front. This passes behind into a pouch, the *radular sac* (*r.s*, Fig. 109; Z, Fig. 110), which lies at the back of the buccal mass, and forms a small rounded protuberance of whitish colour. The surface of the radula is rough, owing to the presence of numerous minute horny teeth. Into the outside of the buccal mass special muscles are inserted, the *buccal protractors* and *retractors*. From the posterior end of the buccal mass a narrow, thin-walled *œsophagus* (*œ*) passes back, and merges into a spindle-shaped crop (*cr*), the thin walls of which are marked by longitudinal striations. The crop narrows behind, and is succeeded by a rounded *stomach* (*st*) with moderately thick walls. This turns sharply upon itself, and is then followed by the narrow, thin-walled *intestine* (*i*), which first bends ventrally, and then, after coiling a little, takes a straight course along the right side of the lung-chamber, where it is called the *rectum* (*r*), to open by the *anus* (*a*). Projecting into the intestinal cavity is a longitudinal fold, the *intestinal valve*, resembling the typhlosole in the Earthworm.

Important digestive glands open into the alimentary canal. These are the salivary glands and the hepato-pancreas (Fig. 109). The *salivary glands* (*s.gl*) are paired branching structures, placed on either side of the crop, to which they are attached by connective-tissue. From each a slender *salivary duct* (*s.d*) runs down the side of the œsophagus, and, dilating slightly, opens into the side of the mouth-cavity.

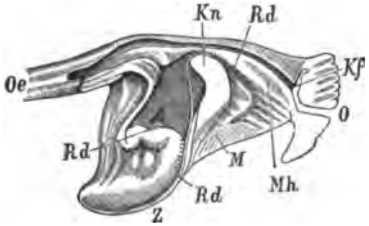

Fig. 110.—Section through Buccal Mass of Snail (from *Claus*, after *Keferstein*).—O, Mouth; Mh, mouth-cavity; M, muscles; Rd, radula; Kn, supporting cartilage; Z, radular sac; Kf, upper jaw; Oe, œsophagus.

The *hepato-pancreas* ("liver") is a large brown organ making up a considerable part of the visceral hump. It is divided into right and left lobes. The latter (*l.l*) is deeply three-cleft, and much larger than the right, which forms the final coils of the visceral hump. There are two *hepato-pancreatic ducts* (bile-ducts), right and left (*r.b.d* and *l.b.d*), running from the corresponding lobes to the right and left sides of the stomach. The left duct is extremely short, and formed by the union of three branches from the sub-divisions of its lobe.

Histology.—The alimentary canal is lined by epithelium, for the most part of the simple columnar type. In the mouth-cavity the radula is a cuticular ribbon, developed by the epithelium lining the radular sac. Upon its upper surface are numerous longitudinal rows of minute, pointed, backwardly-projecting "teeth." Teeth of the same age are at the same level, so that a clear arrangement into transverse rows is also seen. The central row contains symmetrical median teeth (*uncini*) while the lateral (*rachidian*) teeth of the other rows are asymmetrical. As the radula is worn away in front, it grows forwards (like a finger-nail on its bed) upon, and connected with, the *sub-radular membrane,* which covers the projection from the floor of the mouth. This membrane is formed by epithelium, together with underlying connective-tissue, and is to some extent movable upon the central part of the odontophore, which is supported by two masses of gristle, the *odontophoral cartilages* (Fig. 110, Kn). These serve as the origins of minute muscles, which are inserted into the sub-radular membrane in front and behind. The cartilages consist of a clear *matrix,* in which are imbedded numerous branched cartilage cells (*compare Frog*). The wall of the alimentary canal, outside the epithelium, is formed by connective-tissue, external to which are muscular layers, an internal circular and an external longitudinal. The salivary glands and hepato-pancreas are both composed of branched tubules, ending blindly, and lined by glandular epithelium.

4. Circulatory Organs.—As in the Mussel, a **blood system** alone can be distinguished, and the *blood* consists of plasma and white corpuscles. A muscular *heart* is situated in the posterior part of the lung-chamber, in close proximity to the renal organ, and contained in a pericardial cavity* enclosed in a firm translucent *pericardium.* It is oval in form, and made up of an anterior thin-walled *auricle,* which communicates by a valve with a posterior thick-walled *ventricle.* The ventricle is continued into a large artery, the *aorta,* which almost immediately gives off an important visceral artery to the visceral hump, then runs forwards, supplying the body-wall, muscles, viscera, &c., and finally perforates the ventral nerve-mass, after which it breaks up into branches for the head.

The small arteries ultimately end in lacunæ, which communicate on the other hand with large *venous sinuses*. Of these the most important are—two *lateral sinuses* in the foot, a *visceral sinus* along the inner edge of the coiled visceral hump, and a sinus, the *circulus venosus pulmonis*, with which this communicates, running round the floor of the lung-chamber.

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* This does not contain blood.

From the pulmonary sinus numerous *afferent pulmonary vessels* are given off, which branch in the roof of the lung, and from these branches *efferent pulmonary vessels* arise, which unite together to form the *pulmonary vein* opening into the auricle. A number of the afferent trunks enter the renal organ, and form a network within it, from which one large and several smaller *renal veins* run to the pulmonary vein.

Histology.—Compare p. 204.

5. **Respiratory Organs.**—These are represented by a *lung* (pulmonary sac) placed on the upper side of the visceral hump, behind the collar, and communicating with the exterior by a rounded valvular opening on the right side of the body. The delicate roof of the lung is formed by the mantle, and is produced internally into a network of ridges, in which the vessels already described ramify. The convex floor is thin, but muscular, and immediately overlies the crop and the bulk of the reproductive organs.

6. **Excretory Organs.**—A large, cream-coloured *renal organ* or nephridium, somewhat triangular in form, with the apex forwardly directed, is closely united to the posterior part of the lung-roof. It contains a cavity (the surface of which is increased by the projection into it of numerous lamellæ) which communicates with the pericardium by a minute opening, and with the exterior by a *renal duct*. This arises from the anterior end of the renal organ, passes along its right side, and then runs along the side of the lung above the rectum to open close to the anus.

7. **Reproductive Organs** (Fig. 111).—The Snail is *hermaphrodite*. (1.) The hermaphrodite generative gland, *ovo-testis* (*o-t*), is a small yellowish-brown, kidney-shaped organ imbedded in the inner side of the coiled right liver-lobe. From it a whitish (like all the remaining genitals), much convoluted hermaphrodite duct (*h.d*) proceeds.

(2.) **Special Male Organs.**—The duct of the ovo-testis splits as it were into female and male ducts, or oviduct and vas deferens, which convey the ova and spermatozoa respectively. The male duct or vas deferens (*v.d* and *v.d'*), is a narrow tube running at first along the side of the much larger oviduct, the cavities of the two being incompletely separated. In this part of its course (*v.d′*) it is beset with numerous small eminences collectively constituting a *prostate gland*. Lower down the vas deferens (*v.d*) separates from the oviduct, and, after pursuing an independent course for some time, opens into a hollow muscular tube, the *penis* (*p*), which receives at the same point the *flagellum* (*fl*), a long and hollow filament. The penis opens into the *genital atrium*, a shallow depression common to both male and female ducts, and opening to the exterior below the optic tentacle by the genital opening. A narrow band-like muscle, the *retractor penis* (*r.p*), takes origin in the lung-floor, and is inserted into the penis.

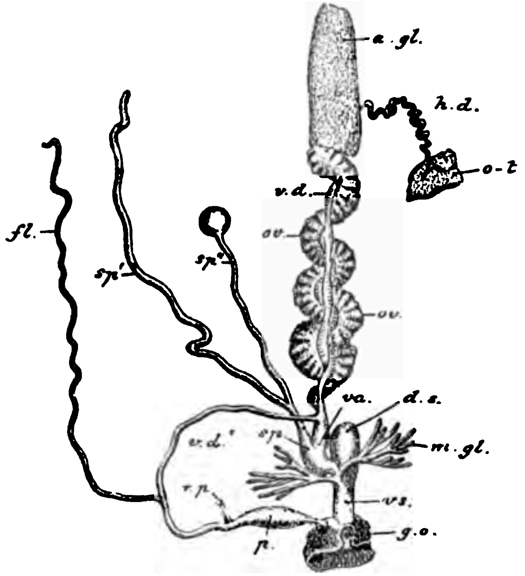

Fig. 111.—Reproductive Organs of Snail.—*o-t*, Ovo-testis; *h.d*, hermaphrodite duct; *a.gl*, albumen gland; *v.d*, vas deferens; *ov*, oviduct; *va*, vagina; *d.s*, dart-sac; *m.gl*, mucous glands; *vs*, vestibule; *g.o*, genital opening; *sp*, spermatheca; *sp′* and *sp″*, left and right branches of ditto; *p*, penis; *r.p*, retractor penis; *fl*, flagellum.

(3.) **Special Female Organs.**—The *oviduct* (*ov*) is a wide, somewhat twisted tube, with folded and pouched walls, along one side of which the vas deferens runs. Into its commencement opens the elongated *albumen-gland* (*a.gl*), which varies very much in size. Where the vas deferens assumes an independent course, the oviduct merges into a short, muscular, smooth-walled tube, the *vagina* (*va*), which opens by a rounded projecting lip into a thick-walled *vestibule* (*vs*). This passes into the genital atrium on the one hand, and on the other becomes continuous with a tubular organ, the *spermatheca* (*sp*), which bifurcates, the right and shorter fork (*sp''*) ending in a berry-like dilatation.

In *Helix pomatia* the left branch is only represented by a small projection.

Two branched *mucous glands* (*m.gl*), open into the side of the vestibule, and lower down an extremely muscular pouch, the *dart-sac* (*d.s*), which can be everted from the genital opening, communicates with it. This sac contains an elongated calcareous body, the *spiculum amoris*, which is sharply pointed and possesses four slightly twisted lateral ridges.

It is doubtful whether the dart-sac really belongs to the female organs, but its position would seem to indicate this.

Histology.—The *ovo-testis* is made up of numerous branched tubules lined with germinal epithelium. The *ova* are developed from the germinal cells lining the blind ends of these tubules, whilst other germinal cells become detached, and form *sperm-morulæ*, much as described for the Earthworm. The ova are rounded, and possess a well-marked *germinal vesicle* with *germinal spot*, but are devoid of a *vitelline membrane*. One or more *polar cells* are probably formed before fertilization. The *spermatozoa* have elongated heads, and slender, very much elongated tails.

8. **Muscular System.**—The walls of the alimentary canal are muscular, and special muscles are connected, as before mentioned, with the buccal mass and odontophore. The walls of the heart and vessels also contain muscle, best marked in the case of the ventricle, and the same may be said of the reproductive ducts, &c., especially the dart-sac and penis. To the last a retractor penis is attached. Sheets of muscle underlie and are closely connected with the skin, and in the lung-floor this becomes of importance in connection with respiration (*see p.* 221).

The *foot* is, for the most part, a mass of muscle-fibres arranged in a complicated manner. The *spindle-muscle,* of which the buccal mass retractors are subdivisions, is mainly inserted into it, while it serves as origin to the protractors and depressors of the buccal mass, and the retractors of the tentacles.

Histology.—The muscle-fibres are composed of spindle-shaped cells, which present indications of transverse striation.

9. Nervous System (Fig. 109).—This is remarkable for its great concentration, and is chiefly localized in the head, where a nerve-ring is found surrounding the gullet, immediately behind the buccal mass in the extended state.

When the animal retracts itself, this is drawn backwards through the nerve-ring, which is therefore then found further forwards than usual.

The ring is covered by a firm sheath, and is formed dorsally by two *cerebral ganglia* (*c.g*), connected together into a transverse band, and united by a double commissure on either side with a ventral ganglionic mass (*v.g*), formed by the coalescence of *parieto-splanchnic ganglia* (dorso-posteriorally), and *pedal ganglia* (ventro-anteriorly).

The head is innervated by branches from the cerebral ganglia, which give off five pairs of nerves. (1) The *tentacular nerves* (*t.n*), which supply the optic tentacles. Each runs within the corresponding tentacle, gives off an *optic nerve* to the eye, and ends in a *tentacular ganglion,* from which branches run to the skin on the end of the tentacle. (2) Two pairs of *labial nerves,* one of which gives off a *tentacular nerve* to the short tentacle, which ends in a *tentacular ganglion.* These nerves supply the lips and neighbouring parts. (3) An *auditory nerve* passes down on either side between the two commissures to the otocyst. (4) A *buccal nerve* (*b.n*) comes off from the front of each cerebral ganglion, and runs forwards to a *buccal ganglion* (*b.g*) placed in the angle where the œsophagus joins the buccal mass. The buccal ganglia supply the odontophore. They are connected together by a commissure ventral to the gullet. The body-walls and viscera are supplied by the *parieto-splanchnic ganglia,* while the nerves of the foot come off from the *pedal ganglia.*

Histology.—The nervous elements are as usual *ganglion-cells* and *nerve-fibres*—the former are confined to the ganglia.

10. Sense Organs—(1.) **Tactile Organs.**—The sense of touch is possessed by the surface of the body generally, but is specially localized in the tentacles. The cells of the epidermis which covers the tip of each tentacle are elongated, and supplied by fibres from the tentacular ganglia. They are doubtless sensory, but their function is uncertain. The tentacles are hollow, and can be drawn into the body by special retractor muscles.

(2.) **Gustatory Organs.**—Not known to be possessed.

(3.) **Olfactory Organs.**—One or both tentacles may have something to do with this, in virtue of the sense-cells above mentioned. An olfactory function has also been ascribed to the *pedal gland*, a tubular organ, lined with columnar epithelium, lodged in the foot, and opening to the exterior by a small pore beneath the mouth.

(4.) **Auditory Organs.**—A minute spherical *otocyst* or *auditory sac* is placed on either side of the ventral nerve-mass, and is connected by an auditory nerve with the corresponding cerebral ganglion. The sac possesses an outer firm investment, and is lined by ciliated columnar epithelium, composed of auditory cells. It is filled with numerous calcareous particles or *otoliths*, suspended in fluid.

(5.) **Optic Organs.**—Each optic tentacle is provided at its termination with an *eye*, which appears as a black dot, and is innervated by the optic nerve. It is placed immediately below the epidermis, a small circular area of which is transparent, and forms a *cornea*. The eye is essentially a spherical vesicle, composed of columnar cells, transparent and thin-walled in front, thickened and pigmented behind, where it forms a sensitive surface or *retina* for the reception of light. The fibres of the optic nerve are connected with the cells of the retina. In the front part of the vesicle a globular transparent *lens* is situated, whilst the remaining space is filled with clear fluid.

PHYSIOLOGY.

1. **Nutrition.**—The *food* of the Snail consists of the fresh leaves, stems, &c., of plants. The radula is used to rasp off small pieces of these, its action being as follows:—The buccal mass is brought forwards by means of its protractor muscles, when the front of the radula on its cushion projects a little from the mouth. The appropriate contraction of the small muscles within the odonto-

phore moves the sub-radular membrane, and with it the radula, backwards and forwards. The upper jaw, meanwhile, holds the food firmly, and serves as a relatively fixed part against which the radula works. The particles of food scraped off pass back into the mouth-cavity, partly by the agency of the flexible lips. The salivary secretion is poured into the mouth-cavity, but its action is not understood. The hepato-pancreatic fluid seems to be of similar nature to that of the Crayfish. The food gets mixed up and gradually passed backwards by the contractions of the muscular walls of the alimentary canal, the length of which gives a considerable absorbing surface, augmented by the intestinal valve.

Circulation.—Blood, oxygenated in the lung, and (part of it) purified in the renal organ, enters the auricle during its diastole by the pulmonary vein. It then passes into the ventricle during the auricular systole. The ventricle, owing to its muscular walls, contracts more vigorously, and the blood, prevented by the auriculo-ventricular valve from returning to the auricle, is forced into the arteries. From the fine ramifications of these it passes into the lacunæ, and thence into the venous sinuses, ultimately reaching the circulus venosus pulmonis. From this the blood, by this time carbonated and loaded with nitrogenous waste, passes by the afferent pulmonary vessels into the roof of the lung. Here it is oxygenated, and passes into the efferent pulmonary vessels from which the pulmonary vein arises. A few of the afferent and a larger number of the efferent pulmonary vessels run into the renal organ, and break up into a network in its walls, from which one large and several smaller *renal veins* arise, that run into the pulmonary vein a little before it enters the auricle.

2. Destructive Metabolism—(1.) **Respiration.**—The respiratory organ is a true *lung*, that is, adapted for breathing ordinary air, while a *gill* breathes air dissolved in water. The floor of the lung when at rest is strongly convex upwards. By its contraction the contained cavity is increased, and air consequently rushes in. This is *inspiration*, the converse of which, *expiration*, is effected by the floor simply ceasing to contract. The pulmonary opening is valvular, and thus the supply of air is regulated and desiccation prevented. The essential part of respiration consists in carbon dioxide diffusing *out of* and oxygen diffusing *into* the vessels ramifying in the lung-roof.

(2.) **Excretion** of nitrogenous waste is effected by the glandular epithelium lining the renal organ, beneath which is a plexus of blood-channels. The urinary excretion passes away by the renal duct.

3. Reproduction.—Self-fertilization is not effected, and it appears that this is prevented by the spermatozoa maturing before the ova. Two individuals copulate, and mutually fertilize each other, the eversible penis being used as a copulatory organ, by which the spermatozoa, bound up into small packets (spermatophores), by a secretion of the flagellum, are conveyed into the spermatheca. On the maturation of the ova, this organ contracts and forces the spermatozoa into the oviduct, where fertilization occurs.

Copulation is preceded by the eversion of the dart-sac, the contained dart being ejected with sufficient force to penetrate the skin of the other individual. The use of this proceeding is not known.

4. Contractility.—The blood-corpuscles and spermatozoa may be cited as examples of **amœboid** and **ciliary movements** respectively.

Muscular Contractions are due to impulses conveyed along motor nerve-fibres. By the contraction of the spindle-muscle the animal can completely withdraw itself into the shell, and at the same time the buccal mass is retracted. Locomotion is effected by wave-like contractions of the muscular foot.

5. Irritability and Spontaneity.—The nerve-fibres are *afferent* (mainly sensory) and *efferent* (mainly motor) as usual. The *cerebral ganglia* appear to be the seat of consciousness and intelligence, so far as they may exist, and of volition. The parieto-splanchnic ganglia, with their nerves, play the part of a **sympathetic nervous system,** in that they regulate the involuntary movements of the digestive organs.

The **sense organs** call for no special notice, except the *eye*, which is "simple," as compared with the "compound" eye of the Crayfish. Light passing through the cornea is concentrated upon the retina by the refractive lens and fluid contained in the vesicle. Internal reflection is prevented by the pigment.

DEVELOPMENT.

1. Early Stages.—The fertilized ova on their way down the oviduct are invested by the glairy secretion of the albumen gland, which sets into a hard protective coating. **Segmentation** is *complete*, but *unequal*, owing to the presence of food-yolk. At its close, one pole of the ovum is occupied by small **epiblast** cells, the other by larger **hypoblast** cells. **Invagination** is effected, and a *gastrula* formed by *epiboly*—*i.e.*, the epiblast grows over and encloses the hypoblast. The **mesoblast** appears first in the region of the blastopore, and ultimately extends everywhere between the other two layers.

2. **General Growth.**—The embryo gradually assumes the characters of the adult by the differentiation of head and foot, and the outgrowth of the visceral hump. Upon this the mantle is formed, the thickened edge of which grows out as a projecting flap, which forms the roof of the lung. The opening into this is wide at first, but the thickened edge of the mantle—in fact, the collar—fuses with the body-wall, so as to ultimately leave only a small respiratory aperture.

3. **Fate of the Germinal Layers.**

(1.) The **epiblast** forms the epidermis, and the epithelium lining the lung, œsophagus, and mouth-cavity. The two last constitute the *stomodæum* (fore-gut). From this the salivary glands grow out, and their epithelium is therefore epiblastic.

The nervous system appears to be formed by epiblastic thickenings, and the eyes arise as pits in the same layer, which close up and become vesicles.

The otocysts originate in the same way.

(2.) The **hypoblast** gives rise to the epithelium lining the alimentary canal, behind the œsophagus, and also to that of the hepato-pancreas, which is an outgrowth from this region.

(3.) The **mesoblast** originates all the rest (*compare p.* 197).

CHAPTER VI.—AMPHIBIA.

§ 9. RANA (The Frog).

The two commonest kinds of Frog are *Rana temporaria*, the Common Frog, and *Rana esculenta*, the Edible Frog. Both are found on the Continent, but only the former in this country. The following description applies to both, any important differences being noted.

MORPHOLOGY.

1. **External Characters.**—The bilaterally symmetrical body exhibits no external trace of segmentation, and is divided into *head* and *trunk*, between which no neck intervenes. There is also no tail. Two pairs of limbs are present, *fore* and *hind*. The surface of the body is soft and moist, and there is no general investing exoskeleton. Owing to the presence of pigment in the skin the body is of a yellowish-brown, and is mottled dorsally. The ventral surface is much smoother and paler than the dorsal. The colour varies with the surroundings.

The flattened **head** is bluntly triangular, with a forwardly directed apex. The *mouth* is extremely wide, and extends backwards to the posterior angles of the head. On the dorsal surface, near the front, are two small valvular apertures, widely separated, the *nostrils* or *external nares*. Behind these are the large projecting *eyes*, with a small, immobile *upper eyelid*, and a delicate, semitransparent *lower eyelid*, capable of considerable movement.

The space between the eyes is broader in *R. temporaria* than in *R. esculenta*, and while flat or convex in the former, is concave in the latter.

Behind each eye is a circular space, the *tympanic area* (larger in *R. esculenta*), which in *R. temporaria* is inside a dark patch of pigment, that tapers to a point behind. In the male *R. esculenta* a pair of *vocal sacs* are found, which, when inflated, form rounded projections near the angles of the mouth.

The **trunk** is somewhat oval, tapering to a blunt point behind, where a small rounded *cloacal aperture* is found. Hard parts can be felt through the skin along the entire dorsal surface, but this is only the case with the *anterior* part of the ventral surface. In this way a *thoracic region* in front can he distinguished from an *abdominal region* behind.

The **fore-limb** commences immediately behind the head, and is divided into (1) *Brachium* (arm), (2) *Antebrachium* (fore-arm), and (3) *Manus* (hand).

If the fore- or hind-limb of an animal is spread out in the *primitive position*, *i.e.*, at right angles to the body, with the "palm" or "sole" side downwards, *dorsal* and *ventral surfaces* can be distinguished. There are also anterior and posterior edges, which, being in front and behind an axial line running down the centre of the limb, are termed *preaxial* and *postaxial edges*.

The manus is *tetradactyle* +, possessing four well-developed digits, and a rudimentary one, concealed under the skin. This last is the *pollex* (thumb), or *1st digit*, the others *2nd*, *3rd*, *4th*, and *5th digits* respectively. The thumb-side is *preaxial*. None of the digits possess nails or claws. In the male Frog, especially during the breeding-season, a thickened pad is found on the *preaxial* side of the palm of the hand, which, in *R. temporaria*, is black.

The **hind-limb** is also divisible into three parts, (1) *Femur* (thigh), (2) *Crus* (leg), (3) *Pes* (foot), with a short cylindrical *tarsus* (ankle), and *five* slender *digits*, united together by a delicate *web*. The *hallux* (great toe), or *1st digit*, is preaxial. It is the shortest, while the *4th digit* is the longest. On the preaxial side of the hallux is a small, horny elevation, the "*calcar*," which is a rudimentary "sixth toe." Hence the pes is *pentadactyle* +.

All the preceding regions, especially the pes, are much longer than the corresponding parts of the fore-limb.

Position of Body.—When at rest the Frog assumes a squatting position, with the ventral surface near the ground posteriorly. The back is humped, marking the union of the sacrum and ilia. The elbow is directed backwards and outwards, and the hand rests with its preaxial side turned sharply inwards. In the hind-limb the knee is directed outwards and slightly forwards, while the crus is bent back parallel to the femur, by which the ankle-joint is thrown behind the body. The pes runs outwards and forwards with its preaxial side internal.

2. Skin (Fig. 112).—The skin is thin, and raised on the dorsal surface into an immense number of minute wart-like protuberances. It is only loosely united to the body, by bands of connective-tissue along certain definite lines. The intervening subcutaneous spaces, over which the skin is baggy, are filled with lymph.

Histology.—A superficial epidermis can be distinguished from an underlying dermis, which is considerably thicker.

The *epidermis* (*Ep.*) is made up of several layers of cells, and hence is classed as *stratified* * epithelium. The most external cells are very flat, without evident nuclei, and make up a *horny layer* (*h.l*). The cells below this are rounded, with well-marked nuclei, and granular protoplasm. Those abutting upon the dermis, forming the *Malpighian layer* (*m.l*), are columnar. A small number of irregular *pigment-cells* (*p.c*), containing dark colouring-matter, are scattered through the epidermis. A large number of glands (*gl*) open upon the surface, the secretion of which makes the skin moist and slippery. These glands are rounded vesicles, lying in the outer part of the dermis, but lined by glandular epidermic cells. They are large and numerous.

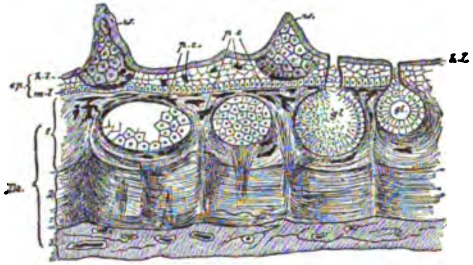

Fig. 112.—Vertical Section of Skin of Frog (after *Wiedersheim*), much enlarged.—*ep*, Epidermis; *h.l*, horny layer; *m.l*, Malpighian layer; *w*, warts; *gl*, cutaneous glands; *p.c*, pigment cells; *De*, 1, 2, 3, layers of dermis.

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* The chief kinds of **Epithelium** may be thus classified :—

I. **Squamous** (Pavement).—Composed entirely, or mostly, of flattened, cubical, or polyhedral cells.	1. *Simple.*—One cell thick. *Endothelium* is a variety of this, composed of flattened cells, and lining heart, vessels, body-cavity, &c. 2. *Stratified.*—More than one cell thick. Epidermis, &c.
II. **Columnar.**—Composed of cells more or less elongated at right angles to surface. May be ciliated.	1. *Simple.*—Stomach and intestine. 2. *Stratified.*—Mouth-cavity of Frog.
III. **Glandular.**—Composed of spherical or cubical cells, which elaborate a secretion or excretion.	For the most part *Simple.*—Peptic glands, kidney tubules, &c., &c.

The *dermis* (*De*) is mainly composed of fibrous* connective-tissue, the fibres of which are mostly parallel to the surface, but also form vertical bands. The glands are imbedded in the external part (1) of the dermis. A large number of pigment-cells (*p.c*) are contained in this part of the dermis. These give to the skin the characteristic colours, which vary owing to the fact that these *chromatophores* contract under the influence of darkness and other stimuli. The pigment can thus be distributed differently.

The glands are surrounded by smooth muscle-fibres (*comp. Fig.* 115), which also form a layer in the deeper part of the dermis (3). This layer is richly provided with blood-vessels, lymphatics, and nerves, which break up into networks. Many of the nerve-fibres end in *touch-corpuscles;* small oval flattened bodies mostly forming groups underneath the epidermal warts.

3. **Endoskeleton** (Fig. 113).—In the Frog and other back-boned animals support is given to the body, protection to certain delicate organs, and points of attachment to muscles, by a number of *internal* hard parts, constituting the *endoskeleton.* This is mainly made up in the Frog of gristle, or *cartilage,* and *bone.* Both of these are modifications of connective-tissue. The bones are largely connected at the joints by fibrous bands (*ligaments*), which resemble tendons in structure (*see p.* 254). Those parts of the endoskeleton belonging to the head and trunk may be conveniently termed *axial,* while those supporting the limbs are *appendicular.*

(1.) *Axial Endoskeleton.*—This consists of the skull, backbone or vertebral column, and breastbone or sternum.

(*a.*) **Skull.**—The groundwork of this is made up of cartilage, constituting the *chondrocranium* or *primordial cranium.* With this are connected bones of two kinds, named, from their mode of development, *cartilage-bones* and *membrane-bones*. The former *replace* pre-existing cartilage, the latter pre-existing connective-tissue. The membrane-bones of the skull are flattened structures investing the other parts, which will be first described.

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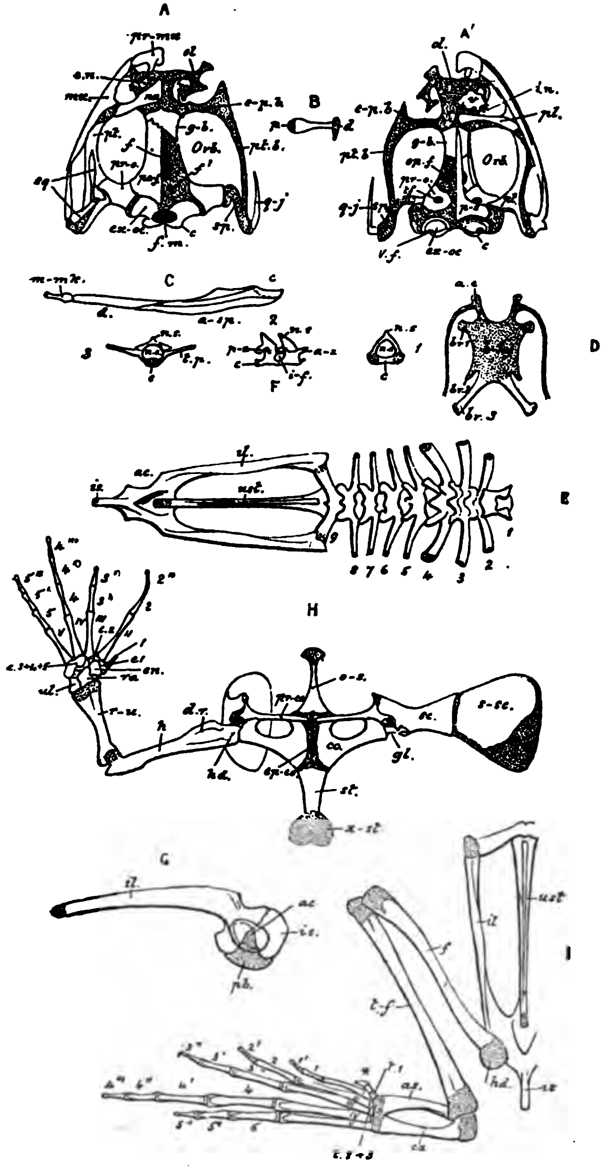
* *Connective-Tissue.*—This in the Frog, Pigeon, and Rabbit, as in the lower animals, permeates the whole body, binding together the other tissues. In the above three forms, and higher animals generally, it consists of three elements, associated together in different proportions. These are:—(1) *Connective-tissue corpuscles,* nucleated cells, often branched (of which pigment-cells are modifications), most abundant in young tissues. (2) *White fibres*—delicate, and wavy, yielding gelatin on boiling. (3) *Yellow elastic fibres,* much branched, or forming networks.

The fibres are developed from the cells. All are imbedded in a structureless *ground substance* or *matrix,* which is semifluid and albuminous.

All these elements are found in the skin and in the bands uniting it with the body-wall.

The *brain-case* (Fig. 113, A,A′) is a narrow tube of cartilage, the upper side of which is broader than the lower, and possesses three spaces, *fontanelles* (*f*, *f′*), a large anterior and two smaller posterior, where cartilage is wanting. These are filled in by connective-tissue. The cavity of the brain-case opens behind by the large *foramen magnum* (*f.m*). The region around this is known as *occipital*, either side of which is occupied by an *ex-occipital* bone (*ex-oc*), upon which is a projection, or *occipital condyle* (*c*), with an oval smooth surface. The two ex-occipitals do not completely bound the foramen magnum, a small cartilaginous strip being left above and below. Each ex-occipital is perforated by a

Fig. 113.—ENDOSKELETON OF FROG (A, A′, and C, after *Ecker*). Cartilage dotted.—A and A′, Skull from above and below, membrane bones stripped off on one side; *f*, *f′*, fontanelles; *f.m*, foramen magnum; *ex-oc*, ex-occipital; *c*, condyles; *v.f*, vagus foramen; *pr-o*, pro-otic; *t.f*, trigeminal foramen; *op.f*, optic foramen; *g.b*, girdle bone; *orb*, orbit; *ol*, nasal capsules; *e-p.b*, ethmopalatine bar; *pt.b*, pterygoid bar; *sp*, suspensorium; *q-j*, quadrato-jugal; *pt*, pterygoid; *pa-f*, parieto-frontals; *p-s*, parasphenoid, half cut away; *sq*, squamosal; *na*, nasals; *v*, vomer; *pr-mx*, pre-maxilla; *mx*, maxilla; *pl*, palatine; *e.n*, external naris; *i.n*, position of internal naris. B. *Columella*, enlarged.—*p* and *d*, Ends fitting into fen. ovalis and fixed to tymp. membrane, respectively. C. *Left half of Mandible*, from outside.—*m-mk*, Mento-meckelian; *c*, condyle; *a-sp*, angulo-splenial; *d*, dentary. D. *Hyoid apparatus.*—*b-hy*, Body of hyoid; *a.c*, anterior cornua; *br*, 1, 2, 3, remains of branchial arches. E. *Spinal Column and Pelvis* (top view). Numbers refer to vertebræ, and are placed near transverse processes.—*ust*, Urostyle; *il*, ilium; *is*, ischium; *ac*, acetabulum. F. *Various Vertebræ.*—1, Atlas, front view; 2, side view of two adjacent vertebræ; 3, back view of vertebra; *c*, centrum; *n.s*, neural spine; *t.p*, transverse process; *a-z*, pre-zygapophysis; *p-z*, post-zygapophysis; *n.c*, neural canal; *i.f*, intervertebral foramen. G. *Side View of Pelvis.*—*il*, Ilium; *pb*, pubis; *is*, ischium; *ac*, acetabulum. H. *Sternum, Shoulder Girdle, and Fore-limb* (*Ventral View*).—*o-s*, Omo-sternum; *st*, sternum proper; *x-st*, xiphi-sternum; *gl*, glenoid cavity; *s-sc*, supra-scapula; *ep-co*, epi-coracoid; *pr-co*, pre-coracoid sheathed by clavicle; *h*, humerus; *hd*, head of ditto; *d.r*, deltoid ridge; *r-u*, radio-ulna; *ra*, radiale; *ul*, ulnare; *cn*, centrale; *c* 1-5, carpalia; I-V, metacarpals; 1-5, phalanges. I. *Hind Limb, &c.* (*ust*, urostyle, &c., as before).—*f*, Femur; *hd*, head of ditto; *t-f*, tibio-fibula; *as*, astragalus; *ca*, calcaneum; *t*, 1-3 tarsalia; I-V, metatarsals; 1-5, phalanges; *, placed by calcar.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vagus foramen through which the vagus and glossopharyngeal nerves leave the skull (*v.f*).

The *auditory capsules* are closely fused with the hind end of the brain-case, one on either side. They are largely cartilaginous, but each is invaded behind by the ex-occipital of its side, while in front the cartilage is replaced by a large *pro-otic* (*pr-o*) bone. This also assists to form the side-wall of the brain-case, and is notched below by the *trigeminal foramen* (*t.f*), through which the trigeminal and facial nerves pass. The auditory capsule contains a cavity of complex shape, in which the essential organs of hearing are contained. On its outer side is a depression, at the bottom of which is a small opening, the *fenestra ovalis*, filled up with membrane in the recent state. Another and smaller opening on the hinder border, the *fenestra rotunda*, is filled up in the same way.

The cartilaginous side-wall of the brain-case is perforated by an *optic foramen* (*op.f*), and smaller foramina are also present. The cartilage forming the front end of the brain-case is replaced by a bony ring, the *sphenethmoid* or *girdle* (*g-b*) bone, which also supports the hinder part of the *olfactory capsules* that lie in front of the skull. The sphenethmoid somewhat resembles a dice-box in shape, and its cavity is divided into two halves by a transverse partition. This marks the anterior boundary of the brain-case, and is perforated by an *olfactory foramen* on either side for the passage of the corresponding nerve. The part of the bone in front of this is divided by a vertical longitudinal partition, into right and left halves.

The *olfactory capsules* (*ol*) are separated from one another by a vertical plate of cartilage continuous with the longitudinal partition of the sphenethmoid. The walls of the capsules are, especially below, mostly composed of cartilage.

Owing to the projection of the sense-capsules a sort of bay, the *orbit* (*Orb*), in which the eye lies, is left on either side of the brain-case. This is bounded in front by a flat piece of cartilage, the *ethmo-palatine bar* (*e-p.b*), which runs out transversely from the floor of the olfactory capsule. On its hinder edge a delicate *palatine* bone (*pl*) is moulded. Externally the bar sends a process forwards, and becomes continuous with a slender *pterygoid bar* (*pt.b*), which passes back on the outer side of the orbit, and fuses behind with the *suspensorium* (*sp*). This is a rod of cartilage directed outwards, downwards, and backwards. Its proximal end is forked, the short limbs of the fork being attached, above and below, to the outside of the auditory capsule. The lower jaw is "suspended" to its distal end, which presents an articular hollow. With this end a small forwardly-directed splint, the *quadrato-jugal* (*q-j*) bone, is united.

The pterygoid bar is largely ensheathed by the anterior ray of the three-rayed *pterygoid* (*pt*) bone, which touches the external end of the palatine in front. The other two rays are shorter. One of them runs inwards, the other along the under side of the suspensorium.

The lower jaw, or *mandible* (*C*), consists of two strongly-curved halves, each of which possesses an axial cartilage, *Meckel's cartilage*, ossified in front into a small *mento-meckelian* (*m-mk*) bone which unites with its fellow in a median *symphysis*. Behind it presents an oval projection, the *condyle* (*c*), which articulates with the suspensorium. Meckel's cartilage is strengthened below and inside by a long *angulo-splenial* (*a-sp*) bone, from which posteriorly a small elevation, the *coronoid process*, projects upwards.

The preceding parts are more or less overlapped by *membrane-bones*. The roof of the brain-case is invested by two long, flat *parieto-frontals* (*pa-f*) which, behind, are bent over so as to protect the upper part of its side walls. The floor of the brain-case is covered by the *parasphenoid* (*p.s*), a dagger-shaped bone, with its "blade" running forwards, its "guards" underlying the auditory capsules, and its extremely short "handle" projecting back between the ex-occipitals. Affixed to the auditory capsule is a T-shaped bone, the *squamosal* (*sq*), the stem of which covers the suspensorium. This bone supports the *tympanic cartilage*, a ring, over which the tympanic membrane is stretched. On the upper side of the olfactory capsules are two triangular *nasal bones* (*na*), the bases of which are directed towards the middle line, their apices outwards and downwards. They form the posterior boundary of the external nares. The cartilaginous floor of each olfactory capsule is partly covered by a somewhat triangular *vomer*, which is widely separated from its fellow. The apex is directed inwards and backwards towards the end of the parasphenoid, and bears a patch of sharp *vomerine teeth*, while the outer and posterior angle of the base is scooped out, and partly bounds the internal naris of its side. The *upper jaw* has a continuous curved outline corresponding to that of the mandible. In front it is formed by the two *pre-maxillæ* (*pr-mx*), small bones meeting in the middle line in front of the olfactory capsules. Each sends a small process upwards and backwards, and its front margin presents a ridge upon which teeth are stuck. On either side an elongated curved *maxilla* (*mx*), which bears teeth, runs back from the pre-maxilla to the quadrato-jugal. In front it lies along the external side of the ethmo-palatine bar and its forward process, and comes into contact with the palatine and pterygoid. In this region it sends a process upwards towards the nasal.

Each half of the mandible possesses a membrane-bone, the *dentary* (*d*), which is a thin splint covering the outside of Meckel's cartilage for rather more than its anterior third.

A series of structures forming the *hyoid apparatus* (D) are connected with the skull, and usually described with it. They are partly related to the auditory apparatus, and partly to the floor of the mouth. The *columella* (B) is a small rod, bony in the centre, which is fixed into the fenestra ovalis by one end (*p*), while the other (*d*) is attached to the inside of the tympanic membrane. The remainder of the hyoid consists of a quadrangular plate of cartilage supporting the floor of the mouth. This is the *body of the hyoid* (*b-hy*). Its angles are produced into anterior and posterior processes (*br* 1 and 2). In front of the former of these two slender, curved rods of cartilage, the *anterior cornua* (*a.c*) arise. Each of these curves backwards round the angle of the mouth to be attached to the auditory capsule just beneath the fenestra ovalis. From the posterior end of the hyoid body two short bony *posterior cornua* or *thyrohyals* (*br* 3) run back, which diverge and enclose between them the laryngo-tracheal chamber.

(*b.*) **Vertebral Column** (E and F).—This is a hollow rod running back from the skull along the dorsal side of the body. The *spinal cord* lies in its cavity. The anterior part of the column is segmented, being made up of nine rings, the *vertebræ* (1-9), while the posterior part, termed the *urostyle* (*ust*), is unsegmented. All are cartilage-bones.

The vertebræ are very similar, except the first and last. Each is a ring (F), the thickened ventral part of which is called the *body* or *centrum* (*c*), while the rest forms the *neural arch*. The successive centra are united firmly together, and are *procœlous*—*i.e.*, concave in front and convex behind. Both surfaces are covered by a thin layer of cartilage. (The 8*th* vertebra is *amphicœlous*, concave on both faces.) Between adjacent arches spaces are left dorsally and laterally. The former are filled up by connective-tissue, while through the latter, or *intervertebral foramina* (*i.f*) spinal nerves take exit. From the upper side of each arch a small *neural spine* (*n.sp*) projects upwards and backwards in the middle line, while on either side of the arch a stout, cartilage-tipped bar, the *transverse process* (*t.p*), runs outwards. Four small projections with smooth articular surfaces stick out from the front and back of the arch. By these *articular processes* or *zygapophyses* the adjoining arches are linked together. Two (*a-z*), the *præ-zygapophyses*, are anterior, and their articular surfaces face upwards and inwards, while the other two (*p-z*) *post-zygapophyses*, are posterior, and their articular surfaces face downwards and outwards, overlapping the præ-zygapophyses of the following vertebra.

The 1*st* vertebra, or *atlas* (F, 1), is devoid of transverse processes and præ-zygapophyses, and the neural spine is rudimentary. The centrum is somewhat thin, and projects forwards between the occipital condyles. These articulate with two large concave facets on the front of the vertebra.

The 9*th* vertebra, the *sacrum*, has very large and strong transverse processes directed outwards and backwards. The centrum is convex in front, and presents a pair of articular tubercles behind, which articulate with corresponding concavities on the front of the *urostyle*. This is a bony rod, somewhat trihedral, and tapering behind to a point tipped with cartilage. It may be regarded as representing a number of vertebræ fused together, of which a ridge running along its dorsal surface corresponds to the united neural spines. Two small foramina open, one on either side, into the canal of the urostyle, a short distance behind its anterior end. Through these the coccygeal nerves take exit, and they, therefore, correspond to intervertebral foramina. The part of the urostyle in front of them is the first of the fused vertebræ, and may possess more or less distinct transverse processes.

More than nine separate vertebræ may be present in abnormal specimens.

(*c*.) **Sternum** (H).—This consists of several cartilage-bones and cartilages placed in the middle line on the ventral side of the thoracic region. In the extreme front a flat, narrow bone, the *omo-sternum* (*o-s*), is found, to the anterior end of which a rounded flap of cartilage is attached, while posteriorly it broadens out and abuts upon certain parts of the appendicular skeleton which separate it from the *sternum proper* (*s.t*). This is a flattened rod of bone, with a core of cartilage. To its hinder end a large, thin, deeply-notched piece of cartilage, the *xiphi-sternum* (*x-st*), is attached.

(2.) *Appendicular Skeleton.*—The endoskeleton of either the fore- or hind-limb is divisible into:—(1) *Limb-girdle*, which is firmly attached to the trunk, and (2) *Free limb*, articulated to the girdle.

(*a.*) **Fore-Limb** (H).—The two *shoulder-girdles* form an incomplete ring almost encircling the body just behind the atlas vertebra. They are firmly fused to one another in the middle line, ventrally, while dorsally they are attached by muscles to the skull and vertebral column. Each girdle is made up of a dorsal and a ventral moiety. At their point of union is a shallow, articular, *glenoid cavity* (*gl*), which affords attachment to the free limb. The dorsal part is made up of:—(a) The *supra-scapula* (*s.sc*), a quadrangular plate of cartilage, more or less calcified and ossified, broad above, where it overlaps three vertebræ, and narrowing downwards to join; (b) the *scapula* (*sc*), an hour-glass-shaped bone, the lower end of which partly forms the glenoid cavity. The ventral part is composed of:—(a) The *coracoid* (*co*) bone, similar in shape to the scapula, and completing the glenoid cavity. With its inner end (b) the *epi-coracoid*, a narrow strip of cartilage, is firmly fused. The two epi-coracoids unite in the middle line ventrally. In front of the coracoid there is an oval space filled with connective-tissue, the *coracoid fontanelle.* This is bounded in front by (c) the *præ-coracoid* (*pr-co*), a transverse bar of cartilage largely ensheathed by (*d*) the *clavicle*, which is *the only membrane bone in the appendicular skeleton.*

The *free limb* is made up of bones supporting the brachium, ante-brachium, and manus. The *humerus* (*h*) is a long bone belonging to the first of these. Like the long bones of the limbs generally, it consists of a central *shaft*, hollow, and containing marrow, and an enlarged *epiphysis* at either end, which is covered by a thin layer of cartilage. The epiphyses remain for a long time distinct from the shaft, with which, however, they ultimately fuse. The proximal end of the humerus forms a rounded *head* (*hd*), which articulates with the glenoid cavity. A prominent *deltoid ridge* (*d.r*) runs from this half way along the anterior (ventral) surface of the bone. The distal end presents a spheroidal surface with which the next bone articulates, and above and below this (pre- and post-axially) are *condylar ridges*. The antebrachium is supported by a short, stout *radio-ulna* (*r-u*). This is a compound bone, made up of a pre-axial *radius*, fused with a post-axial *ulna*. The boundary between these is marked by a groove at the distal end. The proximal end is excavated to receive the corresponding projection on the humerus, with which it forms the elbow-joint, and produced back behind the last into the *olecranon process*, belonging to the ulnar half of the bone. There are two articular projections, one radial, the other ulnar, on the distal end, which help to make up the wrist-joint. The endoskeleton of the manus is made up of the wrist or *carpus*, and the bones of the *digits*. There are six small bones in the carpus, three proximal and three distal. Two of the former, the *radiale* (*ra*) and *ulnare* (*ul*), articulate with the radial and ulnar facets respectively. The third proximal bone, the *centrale* (*cn*), is on the inner (preaxial) side of the radiale. The distal bones are known as *carpalia* (*c*, 1-5). *Carpale* 1 supports the rudimentary 1st digit, *carpale* 2 the 2nd digit, while the much larger third bone represents *carpalia* 3, 4, and 5, and supports the remaining digits. Following the wrist-bones are five slender *metacarpals* (I.-V.), one to each digit. The 1st metacarpal is very small, but is all that represents the 1st digit, while digits 2, 3, 4, 5 are terminated by 2, 2, 3, 3 slender *phalanges* respectively (2-5).

(*b*.) **Hind-Limb.**—The *hip-girdles* (E, G) are closely united to form the *pelvis*, which resembles in shape a two-pronged fork with an extremely short handle. Its posterior part is a rounded plate, laterally compressed, and presenting on either side a deep oval cup, the *acetabulum* (*ac*), with a prominent margin. This cup is for the articulation of the free limb. Nearly half of the plate and acetabulum are formed antero-dorsally by the broad hinder ends of the two "prongs" or *ilia* (*il*), fused in the middle line. Each ilium is continued forwards to the sacrum, to the corresponding transverse process of which its cartilage-tipped end is united. This part of the ilium is laterally flattened, with somewhat concave ventral and convex dorsal edges. Two other elements on either side, *pubis* (*pb*) and *ischium* (*is*), of which the first is cartilaginous, unite with their fellows to form the middle and posterior parts of the plate and acetabulum. The pubes are triangular, and their apices extend to the upper margin of the acetabulum, above which the ilia and ischia unite.

The *free limb* (I.) is composed of bones belonging to the femur, crus, and pes. The first is supported by a long bone, the *femur* (*f*), the slender shaft of which possesses a slight double or sigmoid curve. Its proximal end is enlarged into a rounded *head* (*hd*), which articulates with the acetabulum to form the hip-joint, and its distal end also presents an articular expansion. The bone of the crus, *tibio-fibula* (*t-f*), like that of the antebrachium, is compound. It is made up by the fusion of a preaxial *tibia* with a postaxial *fibula*, the boundaries of which are indicated by grooves and a double marrow-cavity. The shaft is curved, and the ends are expanded into transversely elongated pulleys, which assist in the formation of the knee- and ankle-joints respectively. The bones of the pes are partly those of the ankle, *tarsus*, and partly those of the *digits*. The tarsus is very much elongated, and composed of four bones. Two of these are proximal, and two distal. The proximal ones, *tibialo-intermedium* (*as*) (astragalus), and *fibulare* (*ca*) (calcaneum), articulate with the tibial and fibular sides of the articular surface on the distal end of the tibio-fibula. They are united to each other at either end by their epiphyses. The distal bones, *tarsalia* (*t*, 1-3), are extremely small. One, *tarsale* 1, supports the calcar and 1st digit, the other represents *tarsale* 2 and *tarsale* 3, and supports the 2nd and 3rd digits. The tarsus is succeeded by the *metatarsus* (I.-V.) The base of the calcar is formed by a minute extra metatarsal, while the slender *metatarsals* 1-5 belong to the corresponding digits. A small flattened phalanx completes the calcar, and 2, 2, 3, 4, 3 slender *phalanges* terminate digits 1, 2, 3, 4, 5, respectively.

Histology.—Cartilage and bone may both be considered as modifications of connective-tissue in which the matrix is very plentiful.

The most typical kind of *cartilage* is made up of a clear homogeneous *matrix*, in which are numerous small cavities, lacunæ, connected with one another by fine channels, and containing nucleated *cartilage-cells*. By the division of these, and the deposition of fresh matrix, cartilage grows, especially near its surface, which is covered by a connective-tissue membrane, the *perichondrium*, in which nerves, lymphatics, and blood-vessels run.

The matrix of bone is densely fibrous connective-tissue, impregnated with lime salts, principally carbonate and phosphate. In this are imbedded numerous much-branched *bone-cells*, which lie in *lacunæ* connected by fine tubules, *canaliculi*, into which the cell-processes are continued. Bone may be either *spongy*, as in the epiphyses of long bones and the interior of flat and short bones, or *compact*, as seen in the shafts of long bones and the exterior of flat and short bones. A membrane, the *periosteum*, similar to perichondrium, covers the outer surface of bones. Its inner part is made up of rounded cells, *osteoblasts*, which during growth add fresh layers of bone to the outside. *Membrane* bones are entirely formed in this way, while *cartilage* bones are preformed in solid cartilage, covered by periosteum. Into this solid cartilage processes of the osteoblastic part of the periosteum penetrate to form the *marrow*, which first absorbs the cartilage, and then replaces it by spongy bone. In the shafts of long bones this is absorbed in its turn to form a continuous marrow-cavity.

Cartilage bones can continue to *lengthen* by growth at their ends. The new bone is formed in the way just described, from the cartilage found there.

Bones *thicken* by the addition of layers to the outside, formed by the periosteum.

The vertebral centra contain peculiar cellular cores, the last remnant of an important embryonic structure, the *notochord*.

4. Digestive Organs (Fig. 114).—The wide *mouth*, which reaches back to the tympanic area, and possesses a narrow *upper lip*, leads into a spacious *mouth-cavity*, the back part of which is termed the *pharynx*. More than 100 minute double-pointed *teeth* are affixed to the inner side of the upper jaw. They are attached to the premaxillæ and maxillæ, and are placed in a furrow bounded by the upper lip externally, and a fold of mucous membrane internally.

The *mucous membrane* is a pale, soft, extremely glandular layer which lines the alimentary canal.

On the roof of the mouth are two small patches of *vomerine teeth*, forwardly placed, and borne by the vomers. They are similar to the others. No teeth are present in the lower jaw. On the roof of the mouth, in the extreme front, a number of minute pores are present, the openings of the *internasal gland*.

The vomerine teeth are a little way behind this, and external to each patch is a small, transversely oval opening, the *internal naris.* Still further back two large oval prominences, caused by the eyes, project into the mouth. Near the angle of the jaw, on either side, is a good-sized opening, that of the *Eustachian tube*, which leads to the tympanic cavity. On the floor of the mouth is a narrow, elongated muscular *tongue* (*to*) attached in front. In the quiescent state its forked end is directed backwards. Numerous small elevations cover its surface, some of which, *filiform papillæ*, are narrow-ended; others, *fungiform papillæ*, broad-ended.

Near the angle of the mouth in the male *R. esculenta* an oval opening is present, which leads into a rounded, dilatable *vocal sac.*

Posterior to the end of the tongue there is a longitudinal chink, the *glottis* (*gl*), with firm swollen edges. It leads into respiratory organs.

The mouth-cavity passes behind into a short, wide *gullet* or *œsophagus*, placed in the middle line, and this without sensible demarcation into a narrower tube, the *stomach* (*st*). This passes backwards, gradually narrowing as it does so. The lining of both œsophagus and stomach is raised into longitudinal ridges. At the posterior or *pyloric* end of the latter a well-marked constriction appears, which marks the position of the *pylorus* (*py*) or point at which the cavity of the stomach communicates with that of the *small intestine.* This is a narrow thin-walled tube, the first part of which, the *duodenum* (*d*), forms, together with the stomach, a U-shaped loop, while the rest (*i*) is thrown into several coils. Its lining is raised into transverse folds connected by fainter longitudinal ridges. The end of the small intestine suddenly dilates into a short thin-walled *large intestine* (*l.i*), the wall of which runs forwards dorsally into an extremely short pouch, the rudimentary *cæcum.* It narrows behind and becomes continuous with a chamber, the *cloaca* (*cl*), which opens externally by the small circular *cloacal opening.* The cavity of the large intestine is separated by an annular valve from that of the small. Its lining is at first raised into delicate intersecting ridges, and then into longitudinal folds which pass back to the end of the cloaca, the posterior part of which is lined by ordinary skin.

Two important glands are connected with the alimentary canal—the liver, and pancreas.

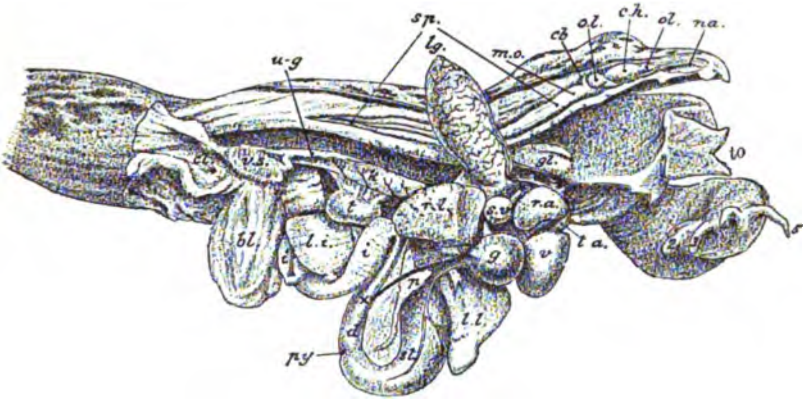


Fig. 114.—Side-Dissection of Male Frog.—2, 3, 4, 5, Digits; *to*, tongue; *st*, stomach, upon which are blood-vessels; *py*, pylorus; *d*, duodenum; *i*, rest of small intestine; *l.i*, large intestine; *cl*, cloaca, opened; *r.l*, and *l.l*, right and left liver-lobes; *g*, gall-bladder; *x*, opening of bile-duct, which is represented by the black line; *p*, pancreas. *s.v*, Sinus venosus, above which is cut end of right precaval; *r.a*, right auricle, above which are the cut ends of carotid arch, systemic arch, and cutaneous artery, while the pulmonary artery is seen running along lung; *v*, ventricle; *t.a*, truncus arteriosus. *gl*, Glottis; *lg*, right lung. *k*, Right kidney, the dark space above which represents the subvertebral lymph-sinus; *u-g*, right urogenital duct, which opens on a papilla in the cloaca (just above the *l.* in *cl.*); *bl*, bladder (its opening is seen just below *l.* in *cl.*) *t*, Testis, above which the vasa efferentia are seen running in the mesorchium; *v.s*, vesicula seminalis. *ol*, Right olfactory lobe, from which right olfactory nerve is seen running forwards; *ch*, right cerebral hemisphere; *o.l*, right optic lobe, passing below and in front into optic tract and nerve; *cb*, cerebellum; *m.o*, medulla oblongata; *sp*, spinal cord. *na*, Right nasal sac.

The *liver* is a very large reddish-brown organ, occupying a considerable space near the front of the body-cavity. It arises as an outgrowth from the alimentary canal, which quickly becomes bilobed. In accordance with this the adult liver is divided into right and left halves (*r.l* and *l.l*), connected by a narrow strip of liver-substance. The left half is again sub-divided into two, so that altogether three *lobes* are present. These are convex ventrally, somewhat concave dorsally, blunt-ended in front, and elsewhere thinning off into edges. The liver secretes the *bile*, a bright yellowish-green fluid. Closely attached to the dorsal surface of the right lobe is a rounded thin-walled sac, the *gall-bladder* (*g*), full of bile, in the fresh state. From it a short tube, the *cystic duct*, proceeds, which is connected with a fine network of *hepatic ducts*, arising from the liver. From this a *bile-duct* is given off, which is reinforced by other hepatic ducts, and runs in the U formed by stomach and duodenum, finally opening into the latter about half an inch beyond the pylorus on the inside of the U (×).

The *pancreas* (*p*) is an elongated yellowish mass lying in the U-shaped loop, and produced into several tapering processes. With it the bile duct is closely connected, receiving from it a number of small *pancreatic ducts.* This gland secretes the *pancreatic juice.*

The digestive and other organs of the Frog are contained in the large *pleuro-peritoneal-* or *body-cavity.* This narrows in front, where it is bounded by the heart in its pericardium, and a kind of muscular partition, the *diaphragm.* It also narrows behind. Its dorsal wall is formed by the backbone and associated muscles, its ventral and lateral walls by hard parts, as well as muscles in the thoracic region, by muscles alone in the abdominal region. The body-cavity is lined ventrally and laterally by a thin pigmented membrane, the *pleuro-peritoneum*, which dorso-laterally becomes free, leaving a space, the *sub-vertebral lymph-sinus* (*above k*), beneath the vertebral column. The two lateral halves of the pleuro-peritoneum run to the middle line, forming a floor to this sinus, and then unite to make a double sheet, the *mesentery*, the halves of which diverge, surround the alimentary canal, and then become continuous. The alimentary canal is thus suspended from the dorsal wall of the body-cavity, and, strictly speaking, is *outside it.* The same may be said of the other contained organs.

Histology.—The wall of the alimentary canal is typically composed of three coats. These are, commencing from the inside—(1) Mucous membrane; (2) Muscular coat; (3) Serous coat.

The *mucous membrane* is the part which is raised into folds, &c. It consists in its deeper part of a framework of connective-tissue, in which numerous blood-vessels, lymphatics, and nerves ramify and form networks. In the stomach and intestine a thin layer of unstriated muscle traverses the centre of this part. It is known as the *muscularis mucosæ.*

Here and elsewhere unstriated muscle is made up of spindle-shaped cells (Fig. 115 each containing an elongated nucleus), which dovetail together by their tapering ends.

The surface of the mucous membrane is covered by *columnar epithelium,* mostly simple, the constituent cells of which possess distinct oval nuclei and clear, free margins. Scattered everywhere throughout the alimentary canal are numerous glandular *goblet-cells,* formed by the metamorphosis of other epithelial cells. The mouth-cavity and commencement of the œsophagus are lined by stratified epithelium, and many of the superficial cells are *ciliated,* numerous cilia projecting from their clear margins. Their shape is somewhat broad and rounded. The tubules of the internasal gland are lined by glandular epithelium. The fungiform papillæ possess *taste-cells* (*see sense organs*). The *teeth* are formed by the mucous membrane. The projecting part or *crown,* which is forked, is separated by a constriction from the rest of the tooth. This last is composed of *cement,* resembling true bone in its structure, and contains a *pulp-cavity,* in which is the *pulp,* a small mass of vascular and nerve-containing connective-tissue. The crown of the tooth is mostly made up of *dentine,* the constituents of which are wavy tubules filled by prolongations of the pulp. The dentine is covered by a cap of extremely hard *enamel,* which exhibits a layered structure, and contains prolongations of the dentine tubules. It is formed by the epithelium of the mouth. The teeth are all very similar, and during life are constantly replaced by new ones, which grow up from their bases.

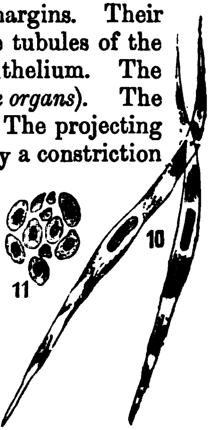


Fig. 115.—UNSTRIATED MUSCLE-FIBRES (from *Landois* and *Stirling*), much enlarged. — 10, Isolated; 11, in cross-section.

The œsophagus and stomach contain numerous *peptic glands,* deep tubular depressions of the epithelium, the ends of which are branched. Their mouths are lined by columnar epithelium, and their branches by glandular epithelium, the cells of which are mostly cuboidal, but (in the stomach) partly ovoid. They secrete the *gastric juice*. The small intestine contains a large number of simple tubular *glands of Lieberkühn*, which lie between the folds and ridges into which the mucous membrane is raised. They are lined by columnar epithelium.

The tongue is largely composed of striated muscle (*see p.* 254). In the œsophagus, stomach, and intestine an unstriated *muscular coat* is present, the thickness of which varies, but is greatest in the stomach. This layer is divided into an outer *longitudinal* and an inner *circular* part.

The *serous coat* is in reality the pleuroperitoneal investment of the œsophagus, stomach, and intestine. It is a thin layer of connective-tissue in which blood-vessels, lymphatics, and nerves run, the branches of which pass in to the mucous membrane.

The *liver* is mostly made up of polyhedral glandular *hepatic cells* (Fig. 149), granular, nucleated, and containing fat drops. Between these cells minute tubes, the *bile-capillaries*, run, forming a complex network from which the ultimate branches of the hepatic ducts arise. The vessels supplying the liver with blood (*see p.* 247) break up into capillaries within it, and in these the branches of the hepatic veins, which carry blood *from* the liver, take their origin.

The ducts of the *pancreas* subdivide considerably, and finally terminate in blind tubules lined by glandular epithelium.

5. Circulatory Organs.—These consist of a closed *blood-system* with which a *lymph-system* communicates.

(1.) **Blood System.**—The *blood* is a bright-red, coagulable fluid, composed of a clear *plasma* in which float *white corpuscles* of the usual type, and larger and more numerous *red corpuscles*, which owe their colour to hæmoglobin. They are oval and flat, with a large central nucleus of similar shape, which projects somewhat on both surfaces of the corpuscle.

The *heart* (Figs. 114 and 116) is situated in the anterior part of the thoracic region, on its ventral side. It is enclosed in a membranous bag, the *pericardium*, which is composed of an inner layer closely adherent to the heart, and a loose outer layer. A space, the *pericardial cavity*, is found between the two. The heart is roughly conical in shape, and its backwardly-directed apex fits into a notch in the liver. Its base is formed by two thin-walled, dark-red *auricles*, right (*r.a* and *Ad*) and left (*As*), the former being the larger, while a muscular, paler *ventricle* (*v* and V) makes up its apical region. A dark-coloured triangular sac (*s.v*), the *sinus venosus*, with thin walls, lies on the dorsal side of the heart, and a muscular tube, the *truncus arteriosus* (*t.a* and B), leading from the right side of the ventricle, is closely applied to the ventral surface of the right auricle, somewhat to the right side.

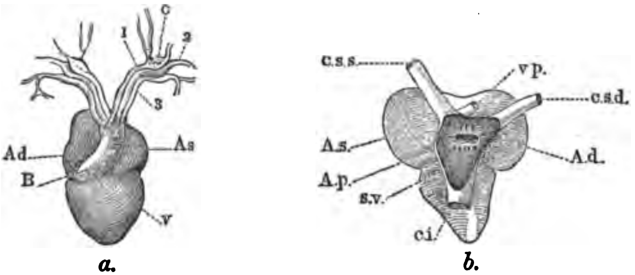


Fig. 116.—Heart of Frog (from *Landois* and *Stirling*, after *Ecker*), slightly enlarged.—*a*, Ventral view; *b*, dorsal view, sinus venosus opened; *s.v*, sinus venosus; *Ap*, its opening into *Ad*, right auricle; *As*, left auricle; *V*, ventricle; *B*, truncus arteriosus; 1, 2, 3, carotid, systemic, and pulmo-cutaneous arches; *c*, carotid gland; *c.s.d* and *c.s.s*, right and left precavals; *c.i*, postcaval; *v.p*, pulmonary vein.

The cavity of the right auricle is separated by a thin muscular partition, the *auricular septum*, from that of the left auricle. Into the dorsal wall of the former cavity, near the septum, the sinus venosus opens by an oval valvular aperture (Fig. 116, *Ap*). There is a somewhat similarly situated rounded aperture in the left auricle, that of the pulmonary veins. The auricles have a common opening into the ventricle, guarded by two flaps, a dorsal and a ventral, which hang down into the ventricular cavity, and are attached to its walls by numerous minute fibrous strings. This auriculo-ventricular valve is imperfectly divided into two by the free posterior edge of the auricular septum, which is attached above and below to the flaps.

The relatively small cavity of the ventricle is transversely elongated, and the ventricular wall which largely bounds it is spongy. The auricles open into the left side, and the truncus arteriosus out of the right side of its front end. The latter opening possesses three *semilunar valves*, small membranous pouches with their concavities towards the truncus. This is divided into two parts—(1) the *pylangium* (into which the aperture just mentioned opens), separated by another set of semilunar valves from (2) the excessively short *synangium*. The cavity of the pylangium is imperfectly divided into right and left halves by a sinuous longitudinal flap attached to its dorsal wall, and to one of the anterior semilunar valves, but possessing a free ventral edge. The passage on the left of this flap leads to a small pulmo-cutaneous aperture just behind the anterior valves, the passage on the right into the synangium. This is continuous on either side with a systemic arch (*see below*), and in front two small carotid apertures, placed on a small elevation, open out of it.

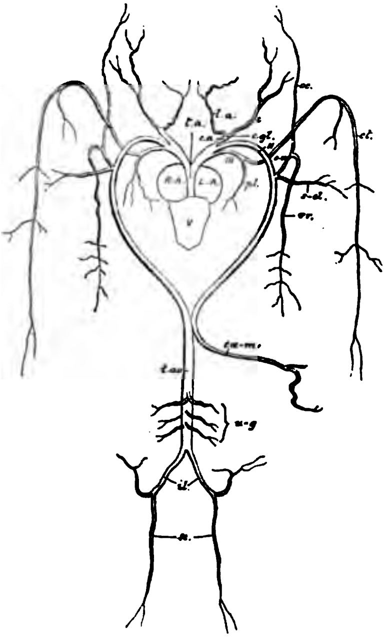


Fig. 117.—Arteries of Frog (after *Ecker*). —R.A, Right auricle; L.A, left auricle; V, ventricle; *t.a*, truncus arteriosus; *c.a*, carotid arch; *c.gl*, carotid gland; *c*, carotid artery; *l.a*, lingual artery; II., systemic arch; *o-v*, occipito-vertebral artery; *oc*, occipital artery; *vr*, vertebral artery; *s.cl*, subclavian artery; III., pulmo-cutaneous arch; *pl*, pulmonary artery; *ct*, cutaneous artery; *d.ao*, dorsal aorta; *cœ-m*, cœliaco-mesenteric artery; *u-g*, urogenital arteries; *il*, iliac arteries; *sc*, sciatic arteries.

The vessels connected with the heart form a *closed* system composed of *arteries*, *veins*, and *capillaries*.

Arteries (Figs. 116 and 117).—From the truncus arteriosus two apparently single trunks arise, one on either side, and form with it a Y-shaped figure. Each of these is in reality triple, its cavity being divided by two longitudinal partitions into three cavities — anterior, middle, and posterior. These belong to three corresponding *aortic arches*—carotid, systemic, and pulmo-cutaneous, into which the trunk soon splits. Into the first and last of these the apertures of the same name lead, and the synangial cavity is directly continuous with the cavities of the systemic arches.

The *carotid arch* (1 and *c.a*) gives off a small *lingual artery* (*l.a*) to the tongue, dilates into a small, rounded body, the *carotid "gland"* (*c*, Fig. 116, and *c.gl*, Fig. 117), and then becomes the *carotid artery* (*c*, Fig. 117), which, after sending branches to the pharynx, eye, and roof of the mouth, enters the skull as the *internal carotid artery* and supplies the brain.

The *systemic arch* (2 and II.) on either side runs upwards and backwards, giving off branches to the laryngo-tracheal chamber and œsophagus, and, near the commencement of the brachium, *occipito-vertebral* (*o.v*) and *subclavian arteries* (*s.cl*). The former divides into the *occipital artery* (*oc*), supplying the outside of the head, and the *vertebral artery* (*vr*), which runs back on one side of the vertebral column to supply its muscles, and sends at the same time branches to the spinal cord through the intervertebral foramina. The *subclavian artery* gives off twigs to the shoulder, and then becomes the *brachial artery* which belongs to the fore-limb. The two systemic arches unite just ventral to the backbone, near the front ends of the kidneys, to form the *dorsal aorto* (*d.ao*), a median trunk running backwards in the subvertebral lymph sinus. At or near their point of union the *cœliaco-mesenteric artery* (*cœ-m*) comes off on the left side, dividing into the *cœliac artery*, which supplies the liver, stomach, and gall-bladder, and the *anterior mesenteric artery*, the branches of which are distributed to the small intestine and spleen. The dorsal aorta runs above the kidneys, giving off from its lower surface several unpaired *urogenital arteries* (*u-g*), which at once bifurcate and run to the urogenital organs and fat-bodies. Near the hinder end of the kidneys a small *posterior mesenteric artery* is given off to the large intestine. At the posterior end of the body the dorsal aorta divides into two *iliac arteries* (*il*), each of which, after sending branches to the bladder and body-wall, becomes the *sciatic artery* (*sc*) which supplies the hind-limb.

Each of the *pulmo-cutaneous arches* (3 and III.) quickly divides into a *pulmonary artery* (*pl*) running down the outer side of the lung (*see* Fig. 114), and a *cutaneous urtery* (*ct*) which ramifies in the skin.

The *veins* (Figs. 116 and 118) bring back blood from the various parts of the body to the heart. They may best be considered under the following headings:—(1) Caval system; (2) Portal systems; (3) Pulmonary veins.

The *caval system* consists of three caval veins with their branches, two precavals in front, and a postcaval behind. These pour their blood into the sinus venosus, which may be regarded as formed by the fusion of their ends (*see Fig.* 116). The *precaval* (*pr-c*) on either side is formed by the union of three veins—(1) The *external jugular* (*ex.ju*), bringing back blood from the lower jaw, floor of the mouth, and tongue; (2) The *innominate* (*in*), formed by the union of the *internal jugular* (*i.ju*) and *subscapular veins* (*s.sc*), which return blood from the brain and shoulder with back of arm respectively; and (3) The *subclavian* (*s-cl*). This is a large vein made up of the *brachial vein* (*br*) from the fore-limb, and the *musculo-cutaneous vein* (*m.ct*), which brings back blood from the muscles and skin of the sides and upper surface of the body and head.

The *postcaval* (*p-c*) lies ventral to the dorsal aorta. It com-

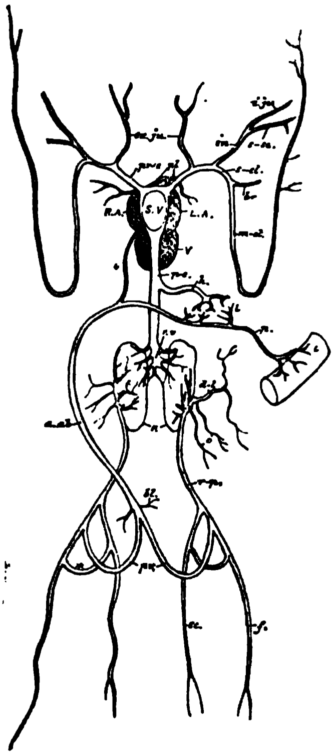


Fig. 118.—Veins of Frog (after *Ecker*), semi-diagrammatic.—*S. V*, Sinus venosus; *R.A*, right auricle; *L.A*, left auricle; *V*, ventricle; *pr-c*, precaval; *ex.ju*, external jugular veins; *i.ju*, internal jugular vein; *s-sc*, sub-scapular vein; *in*, innominate vein; *s-cl*, subclavian vein; *br*, brachial vein; *m-ct*, musculo-cutaneous vein; *p-c*, postcaval; *sc*, sciatic vein; *f*, femoral vein; * cross-branch connecting sciatic and femoral; *p.v*, pelvic veins; *r.p*, renal portal vein; *d-l*, dorso-lumbar veins; *o*, veins from oviduct; *r.v*, renal veins; *a.ab*, anterior abdominal vein; *bl*, veins from bladder; small vein from truncus arteriosus; *p*, portal vein; *h*, hepatic veins; *k*, kidneys; *i*, represents alimentary canal with its capillaries; *l*, represents capillaries of liver; *pl*, pulmonary veins.

mences between the kidneys, and is made up by the union of several pairs of *renal veins* (*r.v*) from those organs, and veins from the genital glands and fat bodies. Just before entering the sinus venosus it receives two *hepatic veins* (*h*), a right and a left, from the liver.

Portal Systems.—A *portal vein* is one which, instead of pouring its blood into a larger trunk, breaks up into capillaries within the substance of some organ, supplying it with impure blood. Both liver and kidneys in the Frog possess such a supply, and in accordance with this, *hepatic portal* and *renal portal* systems can be distinguished.

Renal Portal.—The principal veins of the hind-limb are the *femoral* (*f*) and *sciatic* (*sc*), running along the front and back of the thigh. The femoral vein is connected by a cross-branch (*) with the sciatic just before reaching the trunk, and then divides into a *pelvic vein* (*p.v*) which runs to the middle ventral line to unite with its fellow, and a *renal portal vein* (*r.p*) which runs to the outer side of the kidney, and divides into small veins which break up in the kidney-substance. The renal portal vein receives the sciatic vein, *dorso-lumbar* veins (*d-l*) from the dorsal abdominal walls, and, in the female, small veins from the oviduct (*o*).

Hepatic Portal.—The liver is supplied with impure blood by two veins, the anterior abdominal and portal. The *anterior abdominal* (*a.ab*) is formed by the union of the two pelvic veins, receives veins from the bladder (*bl.*), and runs forwards in the middle line of the abdominal wall as far as the liver. Here it bifurcates, the two divisions going to the right and left halves of the liver. The *portal vein* (*p*) is formed by the union of the *gastric vein*, bringing blood from the stomach, with the *lieno-mesenteric vein* returning it from the spleen and intestines. It runs to the left half of the liver, and is connected by a cross-branch with the point of bifurcation of the anterior abdominal.

A *pulmonary vein* (*pl*) runs up the inner side of each lung, and unites with its fellow to form a short common trunk, which opens into the left auricle (Fig. 116, *v.p*).

The *capillaries* are excessively fine tubes forming networks in all parts of the body, by means of which the ultimate branches of veins and arteries are united. A vein *commences*, an artery *ends*, and a portal vein both commences and ends, in capillaries.

(2.) **Lymph System.**—The *lymph* is a colourless fluid which resembles blood, differing, however, in the absence of red corpuscles. The lymph-system consists of *lymphatic vessels* of larger and smaller size, which ramify in the skin, intestinal wall, and other parts of the body, and *lymph-spaces* with which these vessels are connected. The lymph-spaces include the irregular lacunæ between the tissues, and also larger cavities, such as the pleuroperitoneal, pericardial, subvertebral, and subcutaneous spaces.

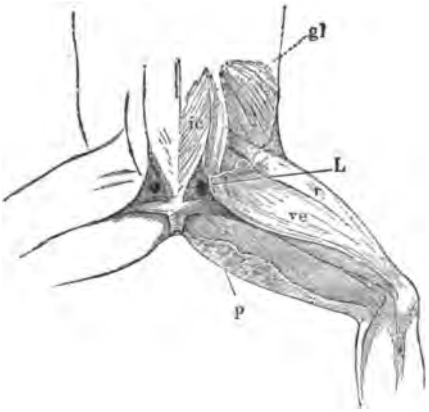
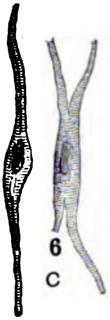


Fig. 119.—Posterior Lymph-Hearts of Frog (from *Landois* and *Stirling*, after *Ecker*).—L, Lymph-heart.

The lymphatics of the intestine, which receive the special name of *lacteals*, traverse the mesentery and open into the subvertebral sinus. The lymph is propelled by two pairs of *lymph-hearts*, small oval sacs, with rhythmically-contractile walls. The anterior lymph-hearts are situated one on either side between the transverse processes of vertebræ 3 and 4, and are connected with the subscapular veins. The posterior lymph-hearts (Fig. 119) are placed one on either side of the urostyle, not far from its posterior end, in a triangular space between the muscles. Each communicates with a small vein which opens into the cross-branch (Fig. 118, *) between the sciatic and femoral veins of its side.

Closely connected with the circulatory system are several small organs whose functions are imperfectly understood. These are the *spleen* and the *thymus* and *thyroid* "*glands.*" The *spleen* is a small rounded body, of dark red colour, lying in the mesentery, near the commencement of the large intestine. The *thymus glands* are two small bodies situated one on either side, near the end of the suspensorium, and the *thyroid glands* are similar structures, two or more in number, placed near the posterior hyoid cornua.



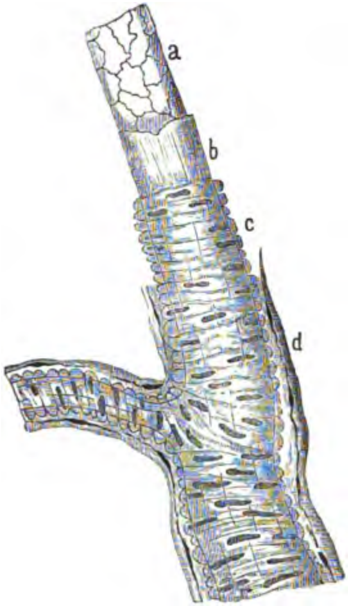


Fig. 120. Fig. 121.

Fig. 120.—Muscle-Fibres from Heart of Frog (from *Landois* and *Stirling*), much enlarged.

Fig. 121.—Small Artery showing the Coats (from *Landois* and *Stirling*).—*a*, Endothelium; *b*, elastic membrane; *c*, muscular coat; *d*, connective-tissue coat.

Histology.—The cavities of the heart and blood-vessels are lined by *endothelium*, which alone forms the capillary walls (Fig. 122). The large lymph-cavities are similarly lined, and patches of granular *germinal* epithelial cells occur in them, from which white corpuscles are budded off. The heart is mainly composed of unicellular, spindle-shaped muscular fibres (sometimes branched), which are transversely striated, but possess no sarcolemma (Fig. 120). The veins and arteries possess three coats outside their endothelial lining (Fig. 121). These are, beginning from the inside—(1) a membrane (*b*) formed by elastic connective-tissue; (2) a muscular coat (*c*) made up for the most part of unstriated muscle-fibres arranged circularly; and (3) a connective-tissue sheath (*d*). These coats are thicker in arteries than in veins, and in large vessels than small. They gradually thin out as capillaries are approached, till at last only endothelium is left (Fig. 122).

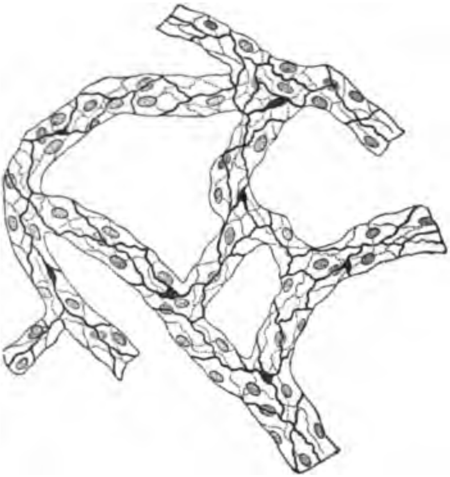


Fig. 122.—CAPILLARIES (from *Landois* and *Stirling*), much enlarged.—The outlines and nuclei of the endothelial cells making up their walls are clearly shown.

6. Respiratory Organs (Fig. 114).—The opening of the *glottis* leads into a small *laryngo-tracheal chamber*, which is firmly fixed between the posterior hyoid cornua. Its walls are strengthened by two triangular *arytenoid cartilages* bounding the glottis, and below these by a *laryngo-tracheal cartilage* of complicated shape. Projecting from the sides of the cavity into its interior are two elastic folds, the *vocal chords*, one on either side. The chamber opens behind into the two *lungs*, which lie freely in the dorsal part of the thoracic region. Each is an elongated thin-walled bag (*lg*), which first dilates and then tapers to a smooth tip. Its inner surface is raised into a prominent series of ridges, which form a close honeycombing.

The *skin* must also be considered as a respiratory organ.

Histology.—The laryngo-tracheal chamber is lined by a continuation of the ciliated epithelium of the mouth-cavity, and the lungs, for the most part, by simple *squamous epithelium.* The basis of these organs is fibrous connective-tissue, with many elastic fibres and a good deal of unstriated muscle. A network of capillaries immediately underlies the epithelium.

7. Excretory and 8. Reproductive Organs.—These are closely related and are best considered together. They often receive the collective name of urogenital organs.

The **excretory organs** (Figs. 114 and 123) are two elongated, flattened, reddish-brown *kidneys* (*k*), symmetrically disposed in the posterior part of the sub-vertebral lymph-sinus. They are covered with pleuro-peritoneum on their ventral surfaces only. From the outer side of each kidney proceeds a slender tube, *urinary duct* in the female, *urogenital duct* (*u-g*) in the male, which opens into the dorsal side of the cloaca, close to its fellow, by a minute slit (just above *cl* in Fig. 114; *u* in Fig. 123). Directly opposite this there is a rounded aperture (just below *cl* in Fig. 114), in the ventral cloacal wall which leads into the *urinary bladder* (*bl*), a large bilobed sac with delicate membranous walls.

Male Reproductive Organs (Fig. 114).—An oval, yellowish, *testis* (*t*), enveloped in pleuro-peritoneum, is closely connected by a double fold of the same, the *mesorchium,* with the inner side of each kidney. In this fold a number of delicate tubules, the *vasa efferentia,* run from one organ to the other. The two testes are commonly unequal in size. In *R. esculenta* the *urogenital duct* is considerably dilated just as it leaves the kidney, and in *R. temporaria* an oval glandular mass, the *vesicula seminalis* (*v.s*), with which it communicates by a number of delicate ducts, is placed on its outer side immediately before it enters the cloaca.

The male Frog is distinguished externally by the characters mentioned on *pp.* 224 and 225.

Female Reproductive Organs (Fig. 123).—The *ovaries* (*ov*) are two flattened sacs, varying much in size according to the season, and situated similarly to the testes. The pleuroperitoneum invests each of them and forms a double suspensory fold, the *mesovarium*. Ova, of various sizes, enclosed in follicles, project on the outer surface of the ovary, and also into the numerous cavities which it contains. The *oviducts* (*od*) are two much-coiled tubes, varying in size even more than the ovaries, according to the season. They are invested in pleuroperitoneum. The narrow anterior end of each oviduct opens near the root of the lungs, by a ciliated funnel (*od'*). The two funnels are close together (*the organs in the fig. have been taken out of the body*), and open into a common ciliated depression. The oviduct widens behind, and at last dilates into a thin-walled *uterus* (*ut*) which opens on a prominent papilla on the dorsal wall of the cloaca (*ut'*). The two papillæ are situated close together just in front of the urinary apertures (*u*, *u*).

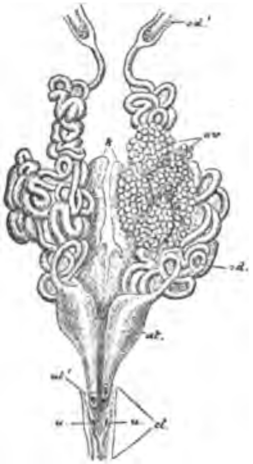


Fig. 123.—**Female Reproductive Organs of Frog** (after *Ecker* and *Wiedersheim*). Right ovary removed.—*ov*, Left ovary; *od*, oviduct; *od'*, funnel of ditto; *ut*, uterus; *ut'*, opening of ditto in cloaca; *k*, kidneys; *u*,*u*, openings of ureters; *cl*, cloaca.

Closely connected with the excretory organs are two anomalous structures, the *adrenals* and *fat-bodies*. The former are two narrow bodies, of yellowish colour, one of which is closely imbedded in the ventral surface of each kidney. The *fat-body* (corpus adiposum) is a bright, orange-coloured tuft of finger-like processes attached to the front end of the kidney of either side.

Histology.—The kidney is mostly made up of a large number of *uriniferous tubules* (*comp. Fig.* 152). Each of these commences in a thin-walled *Bowman's capsule*, lined by delicate squamous epithelium, into which has been pushed from the outside, so to speak, a tuft of capillaries, the *glomerulus*, formed by the breaking up of a branch of one of the renal arteries. The capsule and glomerulus together are known as a *Malpighian body*. A convoluted tubule in which four regions can be distinguished succeeds Bowman's capsule. These regions are (1) a short *neck*, lined with ciliated epithelium; (2) a much convoluted *glandular* part, lined by columnar epithelium which is pigmented and granular; (3) a second ciliated section; and (4) a collecting portion. The last part is connected by a short canal with a ciliated funnel, *nephrostome*, opening on the ventral surface of the kidney.

The *urinary duct* is formed by the union of the collecting portions, and is at first imbedded in the kidney on its outer side. The renal-portal breaks up into capillaries which closely surround the glandular parts of the uriniferous tubules, and are joined by the small veins coming off from the glomeruli.

The *testis* is essentially composed of seminiferous tubules, lined by germinal epithelium, which open into a central cavity. From this the vasa efferentia arise, and, after traversing the mesorchium, enter a longitudinal canal imbedded in the inner edge of the kidney, which gives off numerous transverse tubules. These join the collecting parts of the uriniferous tubules just before they enter the urinary duct. The *spermatozoa* are thread-like bodies, with narrow cylindrical heads and vibratile tails. As in preceding types, they are developed from certain germinal cells known as *spermatospores*. Each of these enlarges and becomes multinuclear, the nuclei being superficial. Most of the nuclei become the heads of spermatozoa, the tails of which are directed *inwards*, but some remain passive. Ultimately a hollow sphere is formed, with the tails projecting into its cavity. This bursts, and the spermatozoa are liberated.

The *ovary* contains numerous ova enclosed in *follicles*, as in the Crayfish. By the rupture of these they escape into the body-cavity. The mature *ovum* is about the size of a small shot. It is covered by a delicate *vitelline membrane*, and possesses granular pigmented *vitellus*, and a large *germinal vesicle* with numerous *germinal spots*. There is reason to believe that *polar cells* (*see Fig.* 93) are formed before fertilization.

The wall of the *oviduct* contains numerous branched tubular glands which secrete a glairy substance, capable of swelling up immensely by imbibition of water. The wall of the uterus contains numerous unstriated muscle-fibres.

The *fat-body* consists of a network of connective-tissue, in the meshes of which numerous *fat-cells* are imbedded. These are spherical bodies full of fat, and covered by a thin layer of protoplasm with a nucleus on one side. They result from the metamorphosis of ordinary connective-tissue cells.

9. Muscular System.—The muscular parts of the internal organs have been already mentioned. The *muscles* proper are very numerous, and have a very complicated arrangement. The following table will give a rough notion of their classification (after Huxley):—

A. Muscles of Head and Trunk.	*Episkeletal*, superficial to the endoskeleton. *Hyposkeletal*, within the endoskeleton.
B. Muscles of Limbs.	*Intrinsic*, taking origin in the limbs themselves (including girdles). *Extrinsic*, taking origin outside the limbs.

The firm endoskeleton affords points of attachment, and this is often effected by the intermediation of *tendons*. The firm sheaths, *aponeuroses*, by which muscles are covered, may also serve for the attachment of other muscles. This is best seen in *flat* muscles, such as some of those forming the abdominal wall.

Histology.—The unstriated muscle-fibres (Fig. 115) and striated muscle-fibres of the heart (Fig. 120) have been dealt with in pp. 241 and 249. The muscles are made up of *striated fibres* (*comp. Fig.* 153), essentially resembling those of the Crayfish (*p.* 175). They possess, however, numerous muscle-corpuscles imbedded in their substance, as well as those just beneath the sarcolemma.

The *tendons* are almost entirely made up of white connective-tissue fibres.

The *motor nerve-fibres* may terminate in *end-plates* (*compare Fig.* 153), within the sarcolemma of striated muscle-fibres, but more frequently the axis-cylinder breaks into a brush of fibrils which run longitudinally in the muscle-substance.

10. Nervous System (Fig. 114).—This may conveniently be subdivided into—(1) cerebro-spinal axis; (2) cranio-spinal nerves; and (3) sympathetic system.

(1.) The **cerebro-spinal axis** is made up of the brain and spinal cord, contained in the neural canal. They are invested by a delicate pigmented vascular membrane, the *pia mater*, and the neural canal is lined by a firm fibrous membrane, the *dura mater*. Between the two is a lymphatic *arachnoid space*, the walls of which are formed by a delicate *arachnoid membrane*.

The **brain** is the anterior enlargement of the cerebro-spinal axis, contained in the cavity of the brain-case. At an early stage of development it consists of three vesicles, anterior, middle, and posterior. The adult parts derived from these constitute the fore-, mid-, and hind-brains. That part of the *fore-brain* which corresponds to the original anterior vesicle is known as the *thalamencephalon*. This contains a vertical slit-like cavity, the *third ventricle*, the anterior boundary of which is a thin lamella of brain-substance, the *lamina terminalis*. The thin roof of the third ventricle is covered by a vascular membrane, the *choroid plexus*, and is connected with a small rounded body, the *pineal "gland,"* by a hollow *pineal stalk*, directed upwards and backwards. The floor is produced downwards in its hinder part into a funnel-like projection, the *infundibulum*, with which a flattened sac, the *pituitary body*, is connected. The much-thickened side-walls are known as the *optic thalami*, and are connected together behind by a small band, the *posterior commissure*. A similar *anterior commissure* runs transversely across through the substance of the lamina terminalis, and connects the corpora striata (*see below*).

The rest of the fore-brain is made up of the structures developed from a pair of lateral outgrowths of the anterior cerebral vesicle. These are—(1) the *cerebral hemispheres* (*c.h*), continuous with the antero-lateral parts of the thalamencephalon, which structure they partly overlap, and in front of which they extend; and (2) the *olfactory lobes* (*o.l*), into which the hemispheres pass anteriorly.

The cerebral hemispheres are smooth, oval bodies, broadest behind, and closely approximated in the middle line. Each contains a *lateral ventricle*, the inner wall of which presents an elevation, the *corpus striatum*, and which communicates with the third ventricle behind by a small aperture, the *foramen of Munro*. The olfactory lobes are two small bodies in front of and continuous with the cerebral hemispheres, from which they are not very clearly marked off. They are closely united in the middle line, and each contains an *olfactory ventricle* continuous with the lateral ventricle of its side.

The *mid-brain* is a small axial part lying immediately behind the thalamencephalon, with which it is directly continuous. It contains a narrow canal, the *Sylvian aqueduct*, which passes in front into the third ventricle. Its roof and side-walls are swollen into two large ovoid *optic lobes* (*o.l*), each of which contains an *optic ventricle* opening into the aqueduct, while its thickened floor is formed by the *crura cerebri*, two masses of longitudinal fibres.

The *hind-brain* is mainly constituted by the *medulla oblongata* (*m.o*), which is continuous in front with the mid-brain, and behind with the spinal cord, which it much resembles in structure. The medulla contains a relatively large *fourth ventricle*, connected by the aqueduct with the third ventricle. Its roof is shaped like a triangle, with forwardly-directed base, and is formed by a vascular membrane. On the under side of the thickened floor is a median groove, the *ventral fissure*. The *cerebellum* (*cb*) is a small, solid, transverse ridge, just behind the optic lobes, which arises as a dorsal outgrowth from the posterior vesicle, and together with the medulla makes up the hind-brain.

The **spinal cord** (*sp*) is a thick-walled tube, somewhat flattened from above downwards, which is contained in the spinal canal. It merges into the medulla oblongata in front, and from this point gradually tapers backwards (dilating, however, where the limb-nerves come off), and ends in a filament, the *filum terminale*, which occupies the canal of the urostyle. The small *central canal* of the spinal cord opens into the fourth ventricle. Dorsally, the cord exhibits a deep cleft, the *dorsal fissure*, and there is a similar *ventral fissure* which passes on to the base of the hind-brain.

(2.) There are twenty pairs of *cranio-spinal* nerves—ten cranial belonging to the brain, and ten spinal belonging to the spinal cord.

Cranial Nerves.—The two first pairs belong to the fore-brain. I. The *olfactory* arise from the outer and front sides of the olfactory lobes, pass through the foramina in the transverse septum of the sphenethmoid, and supply the olfactory epithelium of the nasal sacs. II. The *optic* nerves. On the ventral side of the thalamencephalon there is an X-shaped structure, the *optic chiasma*. The posterior thickened limbs of this, the *optic tracts*, curve backwards and upwards to fuse with the optic lobes. The anterior thinner limbs are the optic nerves. They pass through the optic foramina to reach the eyeballs.

The connection with the optic lobes is a *secondary* one—that is, the optic structures do not originally grow out of them, but fusion occurs later.

The very small third and fourth pairs belong to the *mid-brain*.

III. The *oculo-motor* nerves arise, near the middle line, from the front of its floor, and pierce the side-walls of the skull by special foramina to supply most of the eye-muscles. IV. The *pathetic* (trochlear) nerves are given off from the dorsal surface of the brain, just behind the optic lobes. They pass through foramina in the cranial wall, and supply the superior oblique muscles of the eye.

The remaining six pairs belong to the *hind-brain*, and, with the exception of the sixth, arise from the sides of the medulla oblongata. V. The *trigeminal* are the largest cranial nerves. Each dilates into a *Gasserian ganglion*, leaves the skull by the *trigeminal foramen*, and immediately divides into two—(1) The *orbito-nasal* branch, which runs along the inner side of the orbit, and then divides to supply the olfactory capsule and skin of the snout; and (2) The *maxillo-mandibular* branch. The latter at once bifurcates into—(*a*) The *maxillary nerve*, supplying the teeth and upper lip; and (*b*) The *mandibular nerve*, running round the angle of the mouth and along the outside of the mandible, supplying the skin of that region. Branches from this nerve are also distributed to the muscles of the mouth-floor and to certain muscles which elevate the lower jaw. VI. The very delicate *abducent* nerves arise close together from the ventral surface of the medulla near the front. Each comes into close connection with the Gasserian ganglion, separates from it, and leaves the skull by a small aperture in front of the trigeminal foramen to supply the external rectus and retractor bulbi muscles of the eye, and also the iris. VII. The *facial* nerve on either side arises just behind the trigeminal, and passes out of the skull with it, having previously united closely with the Gasserian ganglion. It divides at once into—(1) The *palatine nerve*, which runs along the floor of the orbit, on its inner side, and supplies the mucous membrane of the mouth-roof; and (2) The *hyomandibular* nerve. This runs back round the auditory capsule, crosses the columella, and then descends in the posterior wall of the tympanic cavity to the angle of the mouth, supplying the regions of the tympanic membrane and jaw-articulation. It then divides into—(*a*) The *mandibular* nerve, running along the inner side of the mandible, giving branches to its superficial muscles; and (*b*) The *hyoid nerve*, which passes along the anterior hyoid cornu and innervates its muscles. VIII. The *auditory* nerves arise

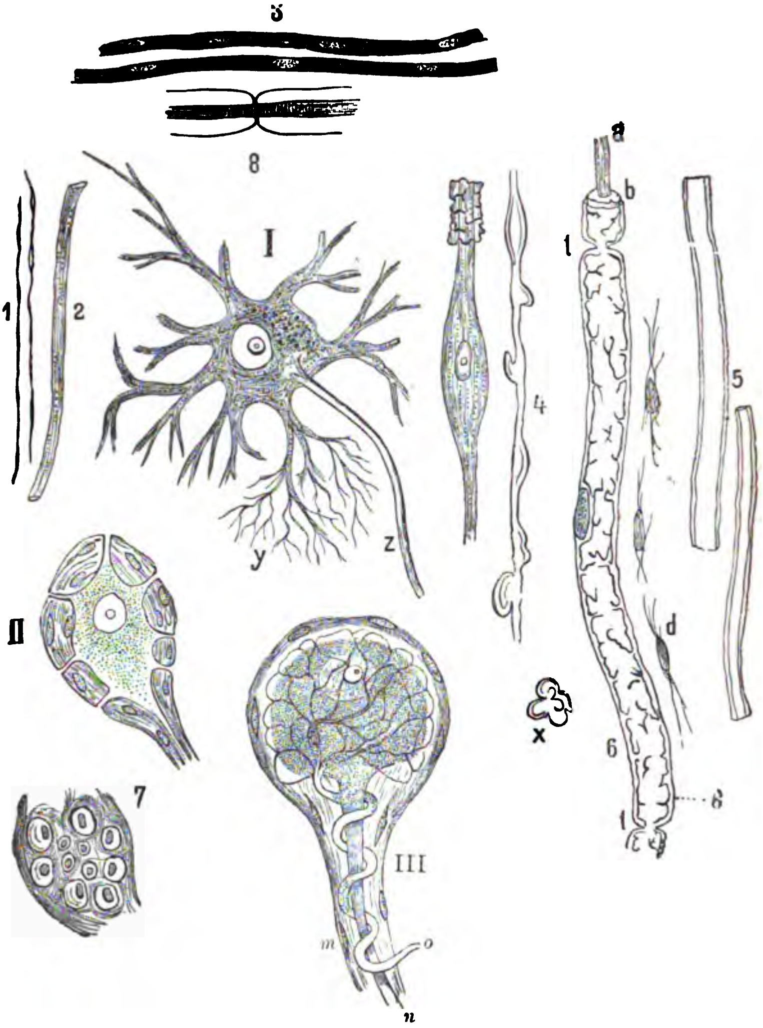


Fig. 124.—HISTOLOGY OF NERVE (from *Landois* and *Stirling*).—1, Primitive fibrillæ. 2, Axis-cylinder. 3, Non-medullated fibres. In their course are seen numerous nerve-corpuscles. 5, 6, Medullated fibres;

c, primitive sheath, internal to which the medulla, *b*, is seen; *t.t*, nodes of Ranvier—between the two a single nerve-corpuscle; *a*, axis-cylinder. 7, Eleven medullated fibres in cross-section, surrounded by connective-tissue; axis-cylinders dark, surrounded by white areas representing medulla. 8, Medullated fibre at node of Ranvier; medulla not shown. I., Multipolar ganglion-cell from spinal cord; *z*, process passing into axis-cylinder; *y*, branched process—to right of this ganglion-cell is a bipolar one. III., Bipolar ganglion-cell from sympathetic of Frog, surrounded by sheath, *m*; *n*, *o*, the two processes.

immediately posterior to the facials, and enter the auditory capsules to supply the essential organs of hearing. IX. The *glossopharyngeal* nerve on either side takes origin a little way behind the root of VIII., and in close connection with that of X. After leaving the skull by the vagus-foramen, it is connected by a commissure with the facial, and then runs down to the floor of the mouth, along which it runs with a tortuous course, supplying the mucous membrane of the pharynx and tongue. X. The *vagus* (pneumogastric) nerve of either side arises in close connection with IX., passes through the vagus-foramen and dilates outside the skull into the vagus-ganglion. It takes a downward and backward course, and gives off branches to the larynx, heart, lungs, and stomach.

The ten pairs of **spinal nerves** have this in common, that each arises from the spinal cord by two roots—a dorsal, upon which is a ganglion, and a ventral. These unite together to form the nerve-trunk in the corresponding intervertebral foramen, which serves as a point of exit. The roots of the anterior nerves pass directly outwards, but the posterior ones slope more or less backwards within the spinal canal before reaching their foramina. The last few roots thus form with the filum terminale, a brush-like *cauda equina*. The ganglia on the roots are covered ventrally by calcareous sacs. Each nerve sends off, near its commencement, a small *dorsal ramus* to part of the muscles and skin of the back, while the remaining part, the *ventral ramus*, is connected by a delicate commissure, *ramus communicans*, with a sympathetic ganglion.

The first or *hypoglossal* nerves run forwards in the throat-muscles and innervate the muscles of the tongue. The second and third unite to form a *brachial nerve*, which supplies the fore-limb. Nerves 4, 5, and 6 supply the body-wall in their region, while nerves 7, 8, and 9 unite to form a network, the *sciatic plexus*, which gives off branches to the posterior viscera, and from which a large *sciatic nerve* arises that innervates the hind-limb. The very small tenth or *coccygeal nerve* proceeds from the foramen in the urostyle, and supplies the posterior viscera. It is also connected with the sciatic plexus.

(3) The **sympathetic system** is made up of a slender cord on either side, lying just beneath the backbone. It is dilated at intervals into ten sympathetic ganglia, each connected by one or more *rami communicantes* with the corresponding spinal nerve. In front it passes through the vagus-foramen, and is united with the Gasserian ganglion, while in the region of the dorsal aorta the two cords are closely bound to the dorsal side of that vessel. The internal organs, including the vascular system, are supplied by branches from the sympathetic ganglia, which break up into plexuses.

Histology (Fig. 124).—The *ganglion-cells* of the cerebro-spinal axis are mostly multipolar (I.) They make up the greater part of the *grey matter*, which forms a central core to the spinal cord, medulla oblongata, optic lobes, and optic thalami, and an external crust to the cerebral hemispheres. The corpora striata are also composed of grey matter. Bipolar ganglion-cells of peculiar type (III.), in which one process is twisted spirally round the other, are found in the sympathetic ganglia, and unipolar cells in the spinal ganglia. The processes of the ganglion-cells either become continuous with the axis cylinders (I., *z*) of nerve-fibres or branch (I., *y*), and form networks.

The nerve-fibres are either *non-medullated* or *medullated*. The non-medullated (3) are made up of *axis-cylinder* and *primitive sheath* with *nerve-corpuscles*. They are the only kind found in the sympathetic system and olfactory nerves, besides which they are common in the other parts of the nervous system. The medullated fibres (5 and 6) possess a layer of fatty matter, the *medullary sheath* (*b*), between the axis-cylinder and primitive sheath. It is broken up into short segments at the *nodes of Schmidt*, and at less frequent intervals *nodes of Ranvier* occur (*t.t* and 8), where the primitive sheath is constricted and touches the axis-cylinder. Each *internodal segment*, bounded at either end by one of these last, generally possesses a single nerve-corpuscle. Medullated fibres make up most of the *white matter* of the cerebro-spinal axis, which forms the external part of the spinal cord, medulla oblongata, optic lobes, and optic thalami, and the internal part of the cerebral hemispheres. The crura cerebri are also of white matter.

Both sorts of nerve-fibres are connected *centrally*, directly or indirectly, with ganglion-cells. Peripherally their axis-cylinders may break up into fine plexuses, or those of medullated fibres may terminate in various *end-bodies*, such as *sense-cells*, and, in the case of striated muscle, *end-brushes* and *end-plates* (Fig. 153).

Non-nervous structures are intimately connected with the nervous system, especially connective-tissue, which forms the investing membranes, and binds the nerve-fibres into smaller and larger bundles, while the fibres and cells of the central organs are imbedded in an excessively delicate connective-tissue network, the *neuroglia*. The pineal gland and pituitary body are both non-nervous. The former is a rudimentary eye.

Sense Organs.—(1.) **Tactile Organs.**—The sense of *touch* is possessed by the skin generally, and the mucous membrane of the olfactory sacs and mouth-cavities. The nerve-fibres connected with this sense are derived from the trigeminal in the head and spinal nerves in the rest of the body. They break up into plexuses, and in the dermis numerous groups of oval flattened *touch-corpuscles* are present. These are most numerous beneath the wart-like elevations, and nerve-fibres are continuous with them.

(2.) **Gustatory Organs.**—Scattered throughout the mouth-cavity, and especially numerous around the vomerine teeth, and on the fungiform papillæ of the tongue, are small groups of elongated *gustatory cells.* They are modified epithelial cells, and fibres of the glossopharyngeal nerves terminate in them.

(3.) **Olfactory Organs.**—A *nasal sac* (Fig. 114, *na*) is lodged on either side of the front of the head, and separated from its fellow by a median partition, the *nasal septum.* The internal cavity is complicated in shape, and communicates with the exterior and mouth-cavity by the *external* and *internal naris* respectively. Its walls are glandular, and largely lined by *olfactory epithelium*, which contains numerous spindle-shaped olfactory cells (Fig. 125, A, *ol, c*) in which fibres of the olfactory nerve end. From these cells a stiff process or bundle of olfactory hairs projects into the nasal cavity.

(4.) **Auditory Organs.**—The *ear* on either side is made up of two parts, (1) Middle ear, and (2) Internal ear.

The *middle ear* consists of a small *tympanic cavity*, communicating by the short *Eustachian tube* with the back of the mouth-cavity, and lined by a continuation of its epithelium. It is closed externally by the rounded *tympanic membrane,* which is stretched over a cartilaginous ring connected with the squamosal and covered externally by skin. The rod-like *columella* (Fig. 113, B) is attached at one end to the tympanic membrane, and stretches across the cavity to the *fenestra ovalis,* into which its other end is inserted.

The *internal ear* is made up of the *membranous labyrinth* (Fig. 125), contained in the cavity of the auditory capsule which, however, it does not fill. Numerous strands of connective-tissue unite it with the walls of this cavity, which is filled by a clear fluid, the *perilymph.* The labyrinth is of complicated shape, and possesses the following parts:—(1) The *utriculus* (*ut*), an irregular bag, the cavity of which is imperfectly bisected by a fold and communicates by a small aperture with that of (2) the *sacculus* (*sc*), an underlying oval bladder. Connected with the utriculus are three curved tubes (3) the *semicircular canals,* (*a*) anterior vertical (*a.v*), (*b*) posterior vertical (*p.v*), and (*c*) external horizontal (*h*). These lie in planes mutually at right angles. The first and last dilate into swellings, *ampullæ* (*ap*), in front, where they join the utriculus. The posterior vertical unites in front with the anterior vertical to form a common tube opening into the utriculus, and dilates behind into an ampulla. (4) Three small swellings on the posterior side of the sacculus receive collectively the name of *cochlea* (*co*).

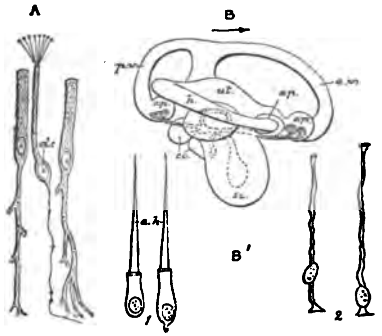


Fig. 125.—Sense Organs of Frog (after *Ecker* and *Wiedersheim*), various scales.—A, Cells from olfactory epithelium; *ol.c*, olfactory-cell. B, Right Membranous Labyrinth, viewed from outside. The arrow points to the front. The branches of the auditory nerve are shown. *ut*, Utriculus; *sc*, sacculus; *a.v*, *p.v*, and *h*, anterior vertical, posterior vertical, and horizontal semicircular canals; *ap*, ampullæ; *co*, cochlea. B′, 1, auditory cells, with auditory hairs, *a.h*; 2, supporting-cells.

The labyrinth is filled with clear *endolymph* in which are suspended, especially near the sensory patches, a large number of calcareous *otoliths*. It is lined throughout by simple epithelium

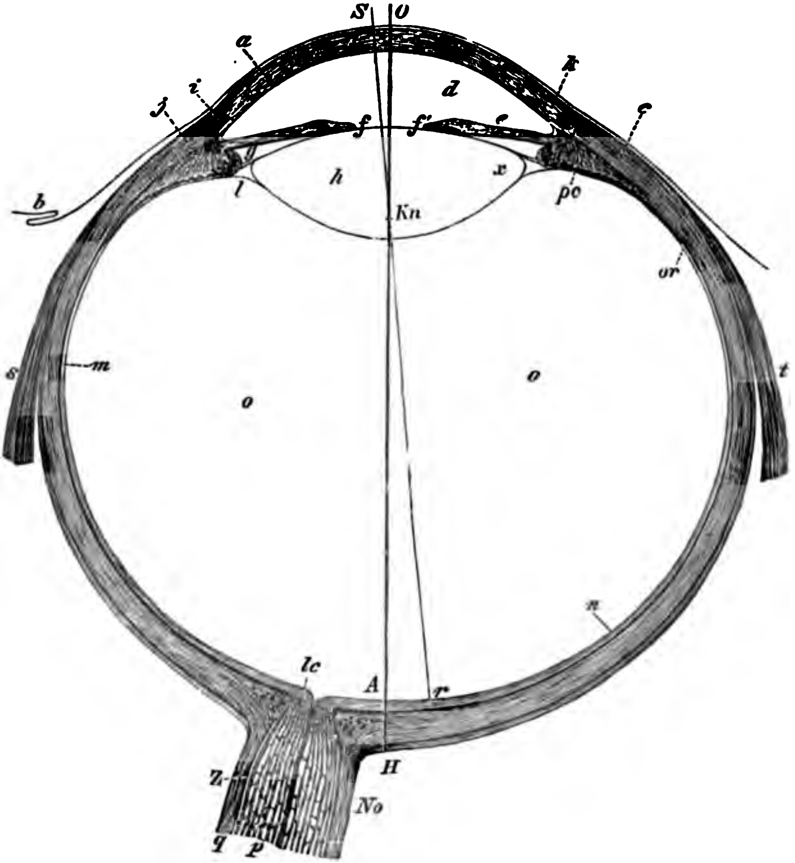


Fig. 126.—DIAGRAMMATIC HORIZONTAL SECTION OF EYE (from *Landois* and *Stirling*).—*a*, Cornea; *b*, conjunctiva; *c*, sclerotic; *d*, anterior chamber, with aqueous humour; *e*, iris; *ff′*, pupil; *h*, lens; *k*, junction of cornea and sclerotic; *m*, choroid; *n*, retina; *o*, vitreous humour; *No*, optic nerve; *q*, nerve sheath; *p*, nerve-fibres, piercing outer coats and becoming continuous with retina.

mostly squamous, but in eight *sensory patches* (B′), largely made up of elongated *auditory-cells*, closely connected with fibres of the auditory nerve. From each a tapering *auditory "hair"* (*a.h*) projects into the labyrinth-cavity. The sensory patches are disposed as follows:—One in each ampulla on a projecting fold, *crista acustica*, and the remaining five, *maculæ*, in utriculus, sacculus (2), and three cochlear projections.

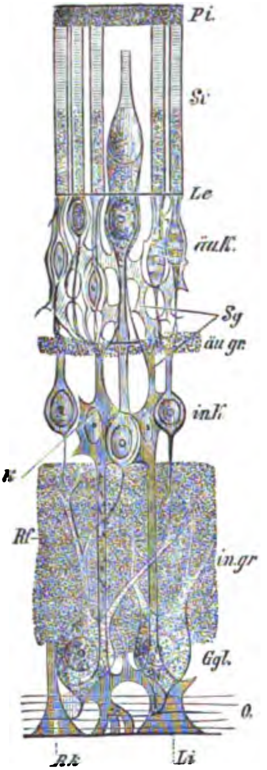


Fig. 127.—DIAGRAM OF LAYERS OF RETINA (from *Landois* and *Stirling*).—*Pi*, Pigment-cells; *st*, rods and cones continuous by various intermediate structures with *G.gl*, ganglion-cells connected with *o*, fibres of optic nerve; *Li*, internal limiting membrane which comes just outside vitreous humour (not shown).

(5.) **Optic Organs** (Fig. 126).—The *eye* is relatively large, and projects not only externally but also internally into the mouth-cavity. It is contained in a bay, the *orbit*, on the side of the skull. The eyeball is approximately globular, and its wall is made up of three concentric coatings. The most external of these, the firm, white *sclerotic* (*c*), strengthened by cartilage, exhibits externally a circular area, the *cornea* (*a*), transparent, and more strongly curved than the rest. The second much thinner coating, the *choroid* (*m*), is pigmented externally and very vascular internally. This layer does not line the cornea, but, at its margin, becomes continuous with a vertical partition, the *iris* (*e*), which presents a central perforation, the *pupil* (*ff′*). By the iris the eye is divided into a small external and a large internal chamber. The latter is lined by the *retina* (*n*), which is the third and most delicate coating. In it eight distinct layers (Fig 127) can be distinguished. The optic nerve (Fig. 126, *p*) pierces the sclerotic and choroid on the inner side of the eyeball to reach the retina, in which it breaks up into a feltwork of fibres (*o*). These form a layer on the internal side of the retina (*i.e.*, the side nearer the eye-chamber), and are connected through various intermediate layers with elongated sense-cells, the *rods* and *cones* (*st*), which occupy the outside of the retina. Refracting structures (Fig. 128) are contained within the chambers of the eye. A clear, watery *aqueous humour* (*d*), fills the external chamber, while a gelatinous *vitreous humour* (*o*) is contained in the internal chamber. Immediately behind the iris and connected with its outer margin is a firm spheroidal body, the *crystalline lens* (*h*).

A number of *accessory* parts are connected with the eye, of which the two *eyelids* have already been mentioned. Continuous with the lining of these is a delicate transparent membrane, the *conjunctiva* (*b*), which closely covers the cornea. A small *Harderian gland* is situated in front of and below the eye. It secretes a fatty substance.

The eye is moved by a number of small muscles, the most important of which take origin in the walls of the orbit, and are inserted into the eyeball. They are—(1) The *retractor bulbi*, a muscular sheath surrounding the optic nerve; (2) the four *recti* muscles, *superior*, *inferior*, *internal*, and *external rectus*, inserted into the upper, lower, anterior, and posterior sides of the eyeball. All the preceding take origin from the inner wall of the orbit, near its posterior end; (3) the two *oblique* muscles, *superior* and *inferior*, are inserted into the upper and lower sides of the eyeball, taking origin close together in the anterior part of the inner wall of the orbit.

PHYSIOLOGY.

1. **Nutrition.**—The food of the adult frog consists mainly of insects. These are secured by the tongue, which can be rapidly protruded and retracted. Its peculiar mode of attachment enables it to be put out to some distance, and being covered with a viscid secretion, insects are easily secured. The secretion of the internasal gland is especially sticky, and the tip of the tongue brushes past its openings when protruded. The teeth are not used for chewing, but to prevent the escape of prey. The cilia of the mouth-cavity work so as to carry the food to the gullet, and from

this point the contractions of the muscular wall of the alimentary canal propel it backwards. The chemical agents acting upon the foods are principally—(1) Gastric juice; (2) Pancreatic juice; and (3) Bile.

The *gastric juice* is secreted by the peptic glands, and in virtue of a ferment, *pepsin*, which it contains, converts some of the proteids into peptones. The ferment can only act in an *acid* solution, and the secretion contains a small amount of free hydrochloric acid. The cuboidal cells of the peptic glands secrete pepsin, while the acid is formed by the ovoidal cells. The *pancreatic juice* contains ferments which (*a*) convert starch into grape-sugar; (*b*) proteids into peptones; and (*c*) split up fats. Alkalinity is necessary for this action, and the *bile* neutralizes any acid passing over from the stomach. It also emulsifies fats, and facilitates their absorption.

The ridges and folds into which the lining of the alimentary canal is raised largely increase its absorptive surface. Some of the products of digestion pass at once into the blood-system, others reach it indirectly by way of the lacteals, sub-vertebral sinus, and lymph-hearts. The refuse is ejected at the cloacal aperture.

Circulation.—The heart receives oxygenated blood from the the lungs by the pulmonary veins, which open into the left auricle. The caval veins pour impure blood from the general body into the right auricle.

The blood in the precavals is partly oxygenated, as they receive the cutaneous veins from the skin, while that in the postcaval is largely free from nitrogenous waste.

The blood is pumped out of the heart by the contraction of its walls. The sinus venosus first undergoes systole, then the auricles together, then the ventricle, and lastly the truncus arteriosus. Systole is followed by diastole, and the various valves prevent regurgitation.

Although the ventricle is single, and receives both kinds of blood, yet these do not completely mix, and the carotid, systemic and pulmo-cutaneous arches, are supplied by oxygenated, mixed, and impure blood respectively. This is explained as follows:— The cavity of the ventricle is transversely elongated. Into its left side the auricles open (their common aperture being rendered *practically* double by the free edge of the auricular septum), and out of its right side the truncus arteriosus. Moreover, its spongy wall absorbs much of the blood received by the auricular systole, and renders mixing more difficult. Just previous to the ventricular systole, the three arches offer different degrees of resistance to the passage of blood—the pulmo-cutaneous least, owing to the small extent of their branches, the carotid most, on account of the spongy carotid glands. When the ventricle contracts, the blood nearest the truncus is impure, as the right auricle tends to fill the right side of the ventricle. This blood takes the direction of least resistance—*i.e.*, runs on the left of the longitudinal septum of the truncus into the pulmo-cutaneous arches. As these are filled, their resistance increases, and blood (now mixed, as sufficient time has elapsed for mixture to commence in the ventricle) flows on the right side of the septum, flapping it over the pulmo-cutaneous aperture, and enters the systemic trunks. Their resistance also increases, and the last portion of blood runs into the carotid arches. This is oxygenated blood from the left auricle, which has been stored up in the spongy wall of the left side of the ventricle.

The large amount of elastic and muscular tissue in the arterial walls subserves two useful purposes. (1) Part of the force of the systoles of the ventricle and truncus is expended in dilating the arteries, which subsequently contract, and continue the pumping work during diastole, so that jerking is avoided. (2) The blood-supply to any part can be regulated. Owing to the influence of the sympathetic system the muscle is usually kept in a semi-contracted state. The same system can cause them to contract more or to contract less, thus diminishing or increasing their calibre.

The thin walls of the capillaries readily allow the blood-plasma to soak out of them, and waste-products to enter them.

The *lymph-hearts* pump lymph into the blood-system. Blood-plasma exuding in excess through the capillaries is thus carried back again, and some of the products of digestion also enter the blood in this way.

2. Destructive Metabolism.—(1.) **Respiration.**—This is effected in the adult Frog by means of the *lungs* and *skin*. Respiration is said to be "buccal," because *inspiration* takes place through the agency of the mouth-cavity, as follows:—The mouth being shut, and the walls of the gullet contracted, appropriate muscles lower the mouth-floor, and thus cause air to rush in by the nostrils. These are then closed, the mouth-floor is elevated, and the air is thus forced into the lungs. *Expiration* is mainly brought about by the elasticity of these organs, and the contraction of the muscle-fibres they contain. The contraction of the abdominal walls may also assist.

The lung-capillaries are only separated from the air contained in the lung-cavities by the epithelium lining these, and their own thin walls. Hence carbon dioxide can readily diffuse out of, and oxygen into, them. A similar interchange takes place between the capillaries of the skin and the oxygen in the surrounding air or water. This cannot take place in air unless the skin is damp.

As in the Earthworm, *hæmoglobin,* in this case present in the red corpuscles, plays an important part in respiration.

Voice is produced by the *vocal chords,* the edges of which can be brought parallel to one another by certain muscles, and then thrown into vibration by the expired air.

(2.) **Excretion.**—The nitrogenous waste (as *urea,* CH_4N_2O), together with much water and various salts, is excreted by the kidneys. The water and salts are filtered from the glomeruli into Bowman's capsules, while the urea is excreted by the glandular parts of the kidney-tubules. The urinary bladder serves as a temporary receptacle for the urine.

3. **Reproduction.**—At the commencement of the breeding-season (early spring for *R. temporaria*), the males affix themselves to the backs of the females, in which process the roughened pads on the hands afford firm attachment. This occurs in the water. The ova burst out from the ovaries, are taken up by the ciliated funnels of the oviducts, and pass down those structures to the uteri, receiving on their way gelatinous investments. Here they are aggregated into "clumps," and expelled by the contraction of the muscle in the uterine and cloacal walls. As they are extruded from the body, sperm is poured over them by the male. Fertilization occurs in the usual way (*comp. Fig.* 94).

4. **Contractility.**—**Amœboid movement** may be seen in the white corpuscles of the blood and lymph, **ciliary action** in the funnels of the oviducts, mouth-cavity, &c.

Muscular Movements.—The muscular tissue is divided into—(1) **Involuntary,** not under the control of the will, including the unstriated fibres of the alimentary canal and blood-vessels, as well as the striated fibres of the heart; and (2) **Voluntary**, under the control of the will, as in the ordinary muscles, which are composed of striated fibres possessing sarcolemma.

5. Irritability and Spontaneity.—The brain and spinal cord are centres of **reflex action.** The spinal cord alone, after the removal of the brain, enables fairly complicated and purposeful movements of the body to be effected, in answer to external stimuli. The cord also serves as a channel by which afferent impulses can travel to the brain, and efferent impulses from it. If the cerebral hemispheres only are removed, still more complicated reflex actions can be evoked by external stimuli, such, for example, as swimming, croaking, and leaping. The medulla

		Afferent.	Efferent.
I.	*Olfactory.*	Sensory fibres for smell.	
II.	*Optic.*	Sensory fibres for sight.	
III.	*Oculomotor.*	... ...	Motor fibres for eye-ball muscles.
IV.	*Pathetic.*		
VI.	*Abducent.*		
V.	*Trigeminal.*	Sensory fibres to skin of head, teeth, and nasal sacs.	Motor fibres to floor of mouth, and certain muscles raising mandible.
VII.	*Facial.*	Sensory fibres to roof of mouth.	Motor fibres to superficial muscles of mandible, and some hyoid muscles.
VIII.	*Auditory.*	Sensory fibres for hearing.	
IX.	*Glossopharyngeal.*	Sensory fibres for taste.	
X.	*Vagus.*	Afferent fibres (some sensory).	Efferent fibres (some motor).
		To parts supplied.	

oblongata, next to the hemispheres, is the most important part of the brain. It regulates respiration, and has much to do (through the sympathetic) with the alimentary canal and circulatory organs. It is also concerned with the co-ordination of many muscular movements.

Spontaneity entirely resides in the cerebral hemispheres. When these are removed, movements only occur after the application of stimuli. They are also the seat of consciousness and intelligence.

The *cranio-spinal nerves* are made up of *afferent* and *efferent* fibres, of which either or both may occur in the same nerve. The preceding table exhibits the leading features of the cranial nerves.

All the *spinal nerves* are of mixed character, the fibres derived from the *dorsal* roots being *sensory*, those from the *ventral* roots *motor*. The sensory-fibres supply the skin, the motor the voluntary muscles of the body; in the case of the hypoglossal some of those belonging to the tongue. The preceding facts have been ascertained by cutting the roots and stimulating the ends, it being remembered that fibres only carry impulses one way, and hence no results follow on stimulating the peripheral ends of sensory, or the central ends of motor, fibres.

Severed.	*Result.*	*Central end stimulated.*	*Peripheral end stimulated.*
Dorsal Root.	Loss of sensation in area supplied, but muscles can be moved at will, or reflexly.	Pain (comes to same thing as over-stimulation of parts supplied).	No effect.
Ventral Root.	Sensation remains in parts supplied, but muscles cannot be moved at will, or reflexly.	No effect.	Muscles supplied contract.

Therefore, the fibres of the dorsal root are sensory, those of of the ventral, motor.

The **sympathetic system** supplies and largely regulates the internal organs. By its means *involuntary* muscular contractions, such as those of the alimentary canal, circulatory organs,

&c., are mainly effected. It is, however, quite subordinate to the brain and spinal cord.

The **sense organs** are here very perfect. In all of them sensory-fibres come into close relation with end-organs of various kinds. *Taste*, not certainly present in the forms hitherto described, is undoubtedly possessed. A substance, to excite this sense, must first be brought into solution. The *auditory organ* presents a great advance. The sound-waves of the air (or water) mostly take the following path:—Tympanic membrane, columella, perilymph, endolymph with otoliths, auditory cells, auditory nerves. The Eustachian tube keeps the air in the tympanic cavity at the same pressure as the external air. The *eye*, by means of its refractive media, can form a picture of surrounding objects on the retina. The rods and cones are the parts of the eye acted on by light, and through them the optic nerve-fibres are affected. The eyeball can be moved up, down, forwards, and backwards, by the superior, inferior, internal, and external rectus muscles respectively, while the oblique muscles effect movements of rotation.

DEVELOPMENT.

1. **Early Stages.—Segmentation** (Fig. 128) is *complete* but *unequal*. The ovum is pigmented on one side, which is termed the *upper pole*, the unpigmented end being the *lower pole*. Divisions may therefore be spoken of as "meridional" or "equatorial." The two first divisions are meridional, dividing the ovum into

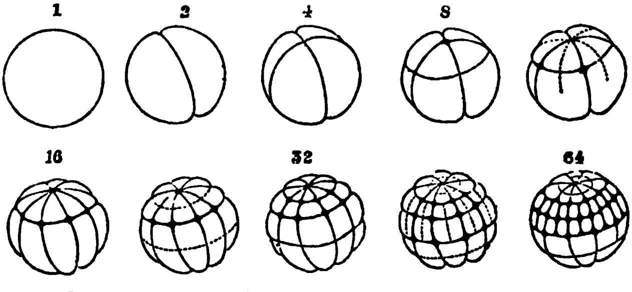


Fig. 128.—Segmentation of Ovum of Frog (from *Haddon*, after *Ecker*).—The numbers indicate the number of segments. Dotted lines show position of succeeding planes of segmentation.

two and four. Then division into eight is effected by an equatorial furrow nearer the upper than the lower pole. Divisions of both kinds now proceed, the final result being a *blastosphere* (Fig. 129, B), with a small *segmentation-cavity* (*bl*) near the upper pole. This is roofed by *small cells*, while its floor and most of the ovum are made up of larger *yolk-cells*, containing food material.

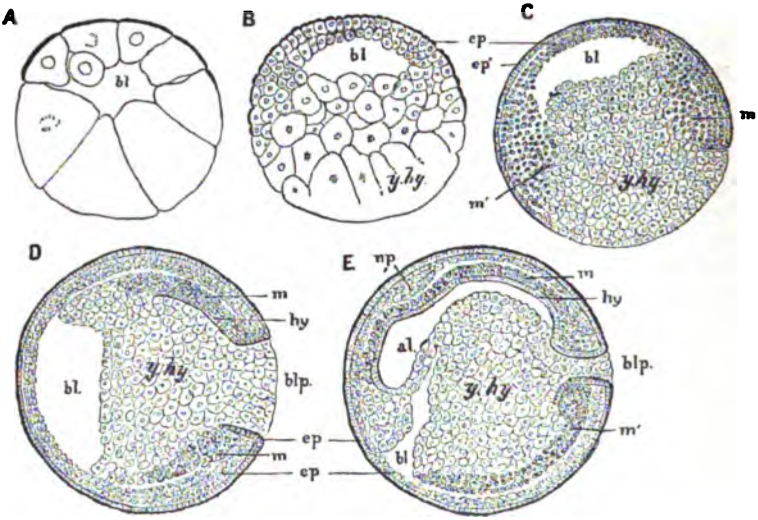


Fig. 129.—Early Stages of Frog (from *Haddon*, after *Götte*). All are sections.—A, Partly segmented egg. B, Completely segmented egg. C, D, E, Stages in formation of gastrula; *al*, archenteron (mesenteron); *bl*, segmentation cavity; *blp*, blastopore; *ep* and *ep'*, nervous and superficial layers of epiblast; *hy*, hypoblast; *m* and *m'*, mesoblast; *y.hy*, lower layer cells.

Invagination (C, D, E) is partly effected by an inpushing of the *small cells* at one point, and partly by their growing over the yolk-cells elsewhere, leaving, however, for a long time an uncovered circular area, the *blastopore* (*blp*). Meanwhile the segmentation-cavity is gradually pushed aside by the *archenteron*, which occupies the upper pole of the ovum, and is formed partly by the inpushing of the small cells, as above stated, and partly by an absorption of the yolk-cells to form a cavity, and their differentiation to give it definite walls. The small cells, now almost covering the ovum, may at this juncture be termed **epiblast** (*ep* and *ep′*), the contained yolk-cells **hypoblast** (*hy*). The *mesoblast* (*m* and *m′*) is formed as a layer several cells thick, commencing at the edges of the blastopore and gradually extending over the rest of the ovum below the epiblast. It is apparently derived from the hypoblast.

2. **General Growth.**—The epiblast on the upper side of the ovum thickens into a *medullary plate*, broad in front, and narrowing behind to the blastopore. The axis of this plate corresponds to the longitudinal axis of the future tadpole, the blastopore being posterior. A delicate *medullary groove* arises on the medullary plate. Its side-walls, the *medullary folds*, grow up and unite together to form a *neural tube*, the rudiment of the brain and spinal cord. The dorsal side of the embryo is thus indicated, and its head and tail soon become evident, the former being marked by the dilation of the neural tube into the three *brain vesicles* in front. The ventral surface bulges out, owing to the food material contained in the hypoblast, but it gradually becomes less and less conspicuous. As growth proceeds, the embryo acquires a strong curve, the dorsal side being concave. The sense organs become established, as also do an oval suctorial mouth with horny beaks, and a cloacal aperture. On each side of the throat six thickened bars, the *visceral arches*, passing from above downwards, are developed. These are termed *mandibular*, *hyoid*, 1st, 2nd, 3rd, and 4th *branchial arches* respectively. From branchial arches 1 and 2 a branched tuft-like *external gill* grows out on either side, and after hatching, which occurs about this period, another proceeds from the third branchial arch. The *tail* now assumes great size and importance as a locomotor organ. In front of each branchial arch a *visceral cleft*, leading into the throat, makes its appearance, and a fold of skin, the *operculum*, grows back from the hyoid arches over the external gills. By the union of this with the body-wall a *branchial chamber* is formed on either side. The right one soon closes, but remains connected by a cross-passage under the throat with the left, which opens to the exterior by a small rounded opening, the *spiracle*. The external gills now shrink and disappear, being succeeded by *internal gills*, minute branched outgrowths from the walls of the clefts. As the lungs develop, these too disappear, and the visceral clefts close up.

The limbs have been arising meanwhile as bud-like outgrowths, the anterior pair being hidden at first by the operculum. They appear at the surface after a shedding of skin which follows the atrophy of the gills. At the same time the eyes become evident, and the horny jaws are cast off. The adult form is now rapidly assumed, the tail gradually shrinking, while vegetable food is given up, and the exclusively aquatic life abandoned.

3. Fate of the Germinal Layers.—(1.) The **epiblast** is early differentiated into superficial and nervous layers (Fig. 129, *ep′* and *ep*). The former gives rise to the horny layer of the epidermis, the deeper part of which is formed from the nervous layer. The epithelium of the mouth-cavity (stomodæum) and posterior part of the cloaca (proctodæum) are also epiblastic, these structures arising as pits of the external surface which at last communicate with the mesenteron to form a continuous alimentary canal.

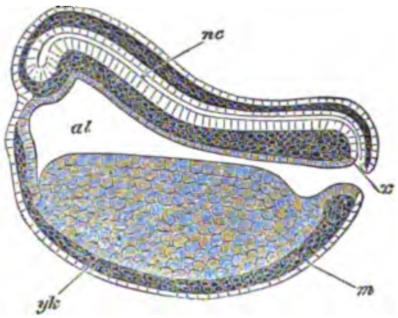


Fig. 130.—Diagrammatic Longitudinal Section through a Frog Embryo (from *Haddon*, after *Götte*).—Epiblast unshaded, hypoblast shaded, mesoblast (*m*) darkly shaded. *n.c*, Neural canal contained within neural tube, which on the left is dilated into the rudimentary brain already exhibiting flexure; *al*, alimentary canal, with mass of yolk (*yk*) beneath; *x*, placed at blastopore, the reference line runs to posterior end of neural canal, which is here continuous with alimentary.

The medullary plate from which the cerebro-spinal axis originates arises as a thickening of the nervous part of the epiblast. The essential parts of the sense organs are epiblastic. The nasal sacs commence as pits in this layer, while the membranous labyrinths are originally depressions of the nervous part of it, which are separated off as vesicles and grow into their complicated adult form. The lens of the eye (*compare Fig.* 143, *l*) is formed as a similar vesicle, which becomes solid. An outgrowth from the anterior cerebral vesicle, the *optic vesicle*, grows towards the embryonic lens, which meets and pushes in its end, forming a double-walled *optic cup*. The part connecting this with the brain narrows to constitute the optic nerve, while the inner wall of the cup becomes the essential part of the retina, the outer part its pigment layer. The rest of the eye is mesoblastic.

(2.) The **hypoblast** gives rise to the epithelium of the mesenteron and its outgrowths (Fig. 130, *al*)—*i.e*, lungs, liver, and pancreas. The visceral clefts are also formed as pouches of the mesenteron. Four of them open as above described (*see p.* 273) to the exterior. In front of these is a pouch which never opens on the surface. This becomes the tympanic cavity. From the hypoblast the first rudiment of the endoskeleton is formed. This is a cellular rod, the *notochord* (*compare Fig.* 144, *ch*), which underlies the nervous system as far forwards as the pituitary body. Remains of it are found in the centra of the adult vertebræ.

(3.) The **mesoblast** at first forms a sheet on either side of the notochord below the epiblast, and also extends into the front of the head. Either sheet splits into an outer *somatic layer*, and an inner *splanchnic layer*, the two remaining united dorsally. The layers of the two sides become continuous ventrally, the split between them forming the body-cavity. The mesoblast on either side becomes divided, posterior to the head, into two longitudinal parts. The upper of these, the *vertebral plate*, lies alongside the neural tube and notochord, and becomes divided transversely into *mesoblastic somites* (protovertebræ). The lower part is known as the *lateral plate*, the *somatic* mesoblast of which unites with the epiblast to form the *somatopleure* (wall of body), while its splanchnic layer unites with the hypoblast to form the *splanchnopleure* (wall of alimentary canal) (*compare Fig.* 144). Both mesoblastic somites and lateral plate are made up of somatic mesoblast externally, and splanchnic mesoblast internally.

The dermis is developed from somatic mesoblast, mostly from that of the lateral plates. The axial endoskeleton is formed from splanchnic mesoblast, that of the mesoblastic somites giving rise to the vertebral column, which, with the hinder part of the base of the brain-case, is moulded round the notochord.

The visceral arches become supported by rods of cartilage, similarly named. Their fate is as follows:—

*I. Mandibular—Suspensoria and Meckel's cartilages.

II.	Hyoid,	Fuse ventrally to form hyoid apparatus.	Columellæ and anterior cornua.
III.	Branchial 1,		Anterior angles of hyoid plate.
IV.	Branchial 2,		
V.	Branchial 3,		Posterior angles.
VI.	Branchial 4,		Posterior cornua.

The rest of the skeleton is also mesoblastic.

The alimentary canal and its outgrowths are formed (except the epithelium) from the splanchnic layer of the lateral plate.

Important changes take place in the *circulatory organs* in connection with the successive appearance of gills and lungs. The heart at first possesses an undivided auricle, and pumps impure blood to the gills by arterial arches corresponding to the last four visceral arches (branchial arches). After the blood has been oxygenated in the gills these arterial arches unite above to form the *dorsal aorta.* They may be named 3, 4, 5, 6, like the visceral arches they traverse. As the lungs develop they are supplied by the 5th arches, and, gradually becoming functional, pour their blood into the auricle, which becomes divided. The internal gills meanwhile atrophy, and the 4th arches alone remain connected to form the dorsal aorta. These changes are best exhibited tabularly.

	1st Stage.	2nd Stage.	3rd (Adult) Stage.
3rd arches,	Supply external gills.	Supply internal gills.	Become carotid arches.
4th arches,			„ systemic „
5th arches,			„ pulmo-cut. „
6th arches,			Disappear.

The adult *kidney* is preceded by a rudimentary excretory organ, the **pronephros.** The duct, *segmental duct,* of this splits into two

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* The *ethmopalatine* and pterygoid bars are a forward outgrowth from this arch.

parts, (1) *Müllerian duct,* which becomes the oviduct of the female; (2) *Wolffian duct,* which becomes the urinary or urogenital duct of the adult. The "kidney," more properly termed the **Wolffian body** or **mesonephros**, is developed as a number of tubules, at first comparatively simple, which become connected with the segmental duct on the one hand, and the body-cavity on the other.

The *ovary* and *testis* are developed as thickenings of the epithelium (and also some of the underlying cells) lining the body-cavity.

The *voluntary muscles* are formed from the somatic layers of the mesoblastic somites.

CHAPTER VII.—AVES.

§ 10. COLUMBA LIVIA (The Rock-Pigeon).

The common Rock-Pigeon is here selected for description, but it must be remembered that the very numerous fancy breeds have all been derived from this form. In some few places the structure of the Fowl (Gallus bankiva) is alluded to, where it differs markedly from the Pigeon.

MORPHOLOGY.

1. **External Characters.**—The bilaterally symmetrical body, in addition to *head* and *trunk*, possesses a long flexible *neck*, and a short stumpy posterior process, the *tail* or *uropygium.* *Fore-* and *hind-limbs* are present, the former modified into wings, the latter set on to the body very far forwards, thus securing equilibrium, and facilitating bipedal progression. The body is largely, but not entirely, covered with *feathers.* These are arranged in certain tracts called *pterylæ*, the intervening bare spaces being known as *apteria.* There are several kinds of feathers, the largest, *quill-feathers,* present on the wings and tail, uropygium, are those principally used in flight. The wing-quills, *remiges,* are 19 in number on each side. They are overlapped,

above and below, by smaller feathers, *wing-coverts.* The tail-quills, *rectrices,* 12 in number, are attached to the uropygium, and are overlapped on both sides by the *tail-coverts.* The small soft feathers, which invest all parts of the body, and confer the characteristic outlines, are *contour-feathers.* In addition to these a very great number of minute rudimentary feathers are present, the *filoplumes.*

The *head* is well rounded behind, while in front it tapers into the *beak,* the upper and lower parts of which are encased in horn, and bound the large *mouth.* A bare elevated area, the *cere,* is present at the base of the upper division of the beak, and in front of this two slit-like *nostrils* or *external nares.* The large *eyes* possess *upper* and *lower* featherless *eyelids,* and each is provided as well with a thin translucent *third eyelid* or *nictitating membrane,* which can be quickly drawn over the eye, or folded up in its anterior angle. A little way behind and below the eye is a rounded *auditory opening* concealed by feathers. It opens into a short tube, the *external auditory meatus.*

The *trunk* is somewhat boat-shaped, presenting a prominent ridge along the middle of its ventral side, except for a small area behind where the soft *abdominal walls* occur. A large transverse *cloacal aperture* with swollen edges, opens ventrally at the base of the tail. Upon the dorsal surface of the latter structure there is a small papilla, upon which the *oil-gland* opens (Fig. 133, *u.gl*).

The *fore-limb* (*comp. Fig.* 132, B) is divided into *brachium, antebrachium,* and *manus,* of about equal length, folded closely upon one another when not extended for flight, but, when so extended, approximating to the primitive position. The manus is *tridactyle,* but the small *pollex* is the only digit well-marked externally. It bears a small tuft of feathers, the *bastard wing.* Eleven of the remiges are attached to the manus. These are the *primary quills.* The remaining eight remiges, *secondary quills,* are attached to the ante-brachium.

The *hind-limb* (*comp. Fig.* 132, C) is divided into *femur, crus,* and *pes.* The last is made up of a cylindrical *tarsometatarsus,* about as long as the femur (the crus is much longer), and four *digits,* of which the first, or *hallux,* is directed backwards, the others forwards. The pes is covered by overlapping *scales,* and the digits are terminated by *claws.*

2. **Skin.**—This is extremely thin. As in the Frog, it is divided into *epidermis* and *dermis*, the former possessing horny and deeper layers. The scales and claws are made up of coalesced epidermic cells, and the *feathers* are also modifications of this layer. One of these last consists of a central *stem*, the proximal part of which, the *quill*, is hollow. This tapers into the solid *shaft*, forming the central part of the expanded *vane*, the rest of which is composed of a row of narrow *barbs* on either side, flattened at right angles to the axis of the feather. Each barb possesses a proximal and a distal row of minute *barbules*. These overlap and hold the barbs together, and, for this purpose, the distal barbules are provided with diminutive hooklets. A minute aperture, the *inferior umbilicus*, leads into the proximal end of the quill, and a similar *superior umbilicus* into its distal end on the ventral side of the feather.

Ventral side = *below* in quill-feathers, *next body* in the others. The shaft is longitudinally grooved on this side.

Position of Body.—The directions assumed by the divisions of the *fore-limb* have already been mentioned. In the standing posture the femur, crus, and tibio-tarsus are arranged in a vertical plane with the knee directed forwards and the mesotarsal ankle-joint backwards. The 1st digit (hallux) is also turned backwards, and owing to its free metatarsal is more mobile than the other forwardly directed digits.

In the Fowl, but not in the Pigeon, a small *after-shaft* is attached near the superior umbilicus, which resembles the vane in structure.

The *filoplumes* possess a minute thread-like stem, but the barbs and barbules are only represented by a tuft of disconnected processes.

The *oil-gland* belongs to the skin. It is made up of numerous branched tubules, epidermic in origin, and lined by glandular-cells.

Histology.—The most important point is the way of development of the feathers. A small papilla is formed on the surface, the base of which sinks down into the dermis and thus becomes enclosed in a pit, the *feather-follicle*, from which its pointed end grows out. The papilla is known as the *feather-germ*. It contains a vascular core of dermis, and the epidermis covering its surface is gradually moulded into the feather. The quill is formed around the base of the germ, the vane around the free part, from which it splits off and expands. The inferior umbilicus is the point where the vascular core entered the feather, the superior umbilicus shows where it left the unsplit quill-part to form the centre round which the vane was once folded.

This description refers to the first-formed feathers. The papillæ of new feathers are formed in connection with the old follicles, and never project on the free surface.

The feathers are renewed periodically during life, the old ones being cast off at moulting.

The *dermis* contains a net-work of muscle-fibres attached to the feather-follicles. By the contraction of this the feathers can be erected. Blood-vessels, lymphatics, and nerves are present, and a large number of ovoid, *tactile corpuscles*.

3. **Endoskeleton.**—This, as in the Frog, is mainly made up of cartilage, cartilage-bones,[*] and membrane-bones.[†]

There are also a few *sesamoid* bones, *e.g.*, patella, developed in the course of tendons.

The bones are distinguished by their spongy character, and the shafts of the long bones contain, in the adult, air instead of marrow.

(1.) **Axial Endoskeleton** (Fig. 131)—(*a.*) **Skull** (*A* and *A'*).—The mature skull contains comparatively little cartilage, and a chondro-cranium is only to be made out in the embryo. The bones in the adult are fused together so as to make the determination of boundaries a difficult matter. A rounded *cranial portion* behind may be distinguished from a tapering *facial* portion in front, the two being connected together by an imperfect joint which permits a small amount of up and down movement. A large rounded *orbit* is present on either side near the junction of the two.

The *cranial* part is mostly made up of the rounded *brain-case.*

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[*] *Cartilage bones:—Basi-*, *ex-*, and *supra-occipitals*, *pro-*, *epi-*, and *opisth-otics*, *basi-*, *pre-*, *ali-*, and *orbito-sphenoids*, *mesethmoid*, *quadrate*, *articular*, *columella*, *basihyal*, *basibranchial*, *posterior cornua* of hyoid. *Vertebræ. Sternum. Ribs. Appendicular skeleton* (except furcula).

[†] Membrane bones:—Parietal, frontal, squamosal, parasphenoid, lachrymal, basitemporal, vomer, nasal, premaxilla, maxilla, jugal, quadrato-jugal, pterygoid, palatine, angular, supra-angular, dentary, splenial. Furcula.

This exhibits a large *foramen magnum* (*f.m*) behind, bounded by the occipital region, to form which four bones are fused together two *ex-occipitals* (*ex-oc*) at the sides, a *supra-occipital* (*s-oc*) above, the anterior margin of which is marked by a transverse *lambdoidal ridge*, and a *basi-occipital* (*b-oc*) below, which bears a median rounded *occipital condyle* (*c*). The roof of the brain-case is completed by two pairs of bones, the *parietals* (*pa*), and *frontals* (*fr* and *fr′*). It narrows considerably in front. The parietals behind and, anterior to them, the frontals, fuse with one another in the middle line. A slight ridge running forwards from the lambdoidal ridge, and passing into a groove marks this union. The side-wall of the brain-case is partly formed by the *squamosal* (*sq*), below which is a depression, the *tympanic cavity* (*ty*), bounded internally by the *auditory capsule.*

This is formed by the union of three elements, *pro-otic*, *epi-otic*, and *opisth-otic*, of which the first is most important. They are placed in front, above, and behind respectively.

About the centre of the capsular wall are two small openings, one above the other, separated by a very narrow interspace. The upper is the *fenestra ovalis* (*reference line of ty points to this*), the lower the *fenestra rotunda.* Into the front of the tympanic cavity the Eustachian tube opens.

Further forwards the brain-case is bounded laterally by an *orbital plate*, which also forms the hinder and upper parts of the wall of the orbit. This is made up below by the *ali-sphenoid* (*a-s*), which is fused with the squamosal behind, and then curves rapidly inwards, and above by the *orbital process* (*fr′*) of the frontal, which turns sharply downwards and inwards. The floor of the brain-case in front of the basi-occipital is formed by the *basi-sphenoid.* From this a pointed rod, the *para-sphenoid* or *basi-sphenoidal rostrum* (*p-s*), projects forwards. It is fused with the lower edge of a thin bony plate, the *inter-orbital septum* (*i-o. s*), continuous behind with the ali-sphenoids. This posterior part of the septum represents three distinct bones, a median *pre-sphenoid,* and two lateral *orbito-sphenoids.* The upper and anterior parts of the septum are in the young bird a distinct bone, the *mesethmoid.* The anterior margin of the orbit is formed at this point by the *lachrymal.* The basi-sphenoid is overlapped by a thin plate of bone, the *basi-temporal* (*b-t*), which forms the lower boundary of

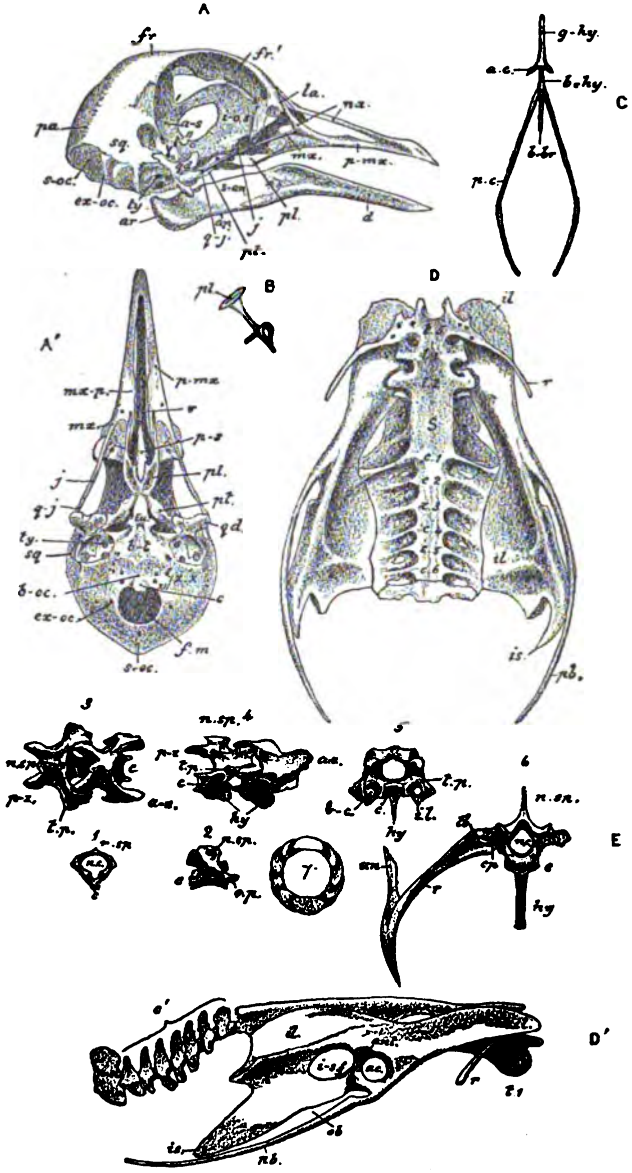
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Fig. 131.—Endoskeleton of Pigeon (Cartilage dotted).—A and A′, Skull, side and under views; *s-oc*, supra-occipital; *ex-oc*, ex-occipital; *b-oc*. basi-occipital; *c*, condyle; *pa*, parietal; *sq*, squamosal; *a-s*, ali-sphenoid; *fr*, frontal; *fr′*, orbital process of ditto; *i-o.s*, inter-orbital septum; *la*, lachrymal; *b-t*, basi-temporal; *p-s*, basi-sphenoidal rostrum; *v*, vomer; *na*, nasal; *p-mx*, pre-maxilla; *mx*, maxilla; *mx-p*, maxillo-palatine process: *j*, jugal; *q-j*, quadrato-jugal; *pl*, palatine; *pt*, pterygoid; *qd*, quadrate; *d*, dentary; *ar*, articular; *an*, angular; *s-an*, supra-angular; *ty*, tympanic cavity (reference line runs to fenestra ovalis); *Eu*, Eustachian opening; *f.m*, foramen magnum. I., II., &c., Nerve exits. (V., just *above* foramen for fifth.) B, *Left columella*, enlarged; *pl*, plate fitting into fenestra ovalis. C, *Hyoid apparatus*, from above; *g-hy*, glosso-hyal; *b-hy*, basi-hyal; *b-br*, basi-branchial; *a.c*, anterior cornua; *p.c*, posterior cornua. D and D′, "*Sacrum*" and *pelvis*, under and side views, numbers refer to vertebræ; *t*, thoracic (wrongly numbered 1 instead of 5); *l*, lumbar; *s*, sacral; *c*, caudal; *c′*, free caudal; *p-sh*, plough-share bone; *r*, rib; *il*, ilium; *pb*, pubis; *is*, ischium; *ac*, acetabulum; *ant*, anti-trochanter; *ob*, obturator fissure; *i-s.f*, ilio-sciatic foramen. E, 1–6, Vertebræ. 1, Atlas: 2, axis: 3, two free cervical, from above: 4, ditto, from side: 5, ditto, from front: 6, first thoracic; *c*, centrum; *n.sp*, neural spine; *t.p*, transverse process; *hy*, hypapophysis; *a-z*, pre-zygapophyses; *p-z*, post-zygapophyses; *o.p*, odontoid peg; *i.l*, cervical rib; *n.c*, neural canal; *v.c*, vertebrarterial canal; *r*, vertebral rib; *cp*, head; *tb*, tubercle; *un*, uncinate process: 7, sclerotic ring.

the tympanic cavity on either side. It tapers somewhat in front, and between it and the basi-sphenoidal rostrum is a median Eustachian opening (*Eu*), from which an Eustachian tube leads back on either side to the corresponding tympanic cavity.

The cavity of the brain-case closely corresponds with the shape of the brain. Its floor is very steep, rapidly ascending towards the front. The foramen magnum looks downwards in accordance with the upright position of the neck.

Nerve Exits.—The *olfactory foramen* (I.) is in the front of the brain-case. A vacuity in the dry skull at the upper margin of the interorbital septum marks the course of the olfactory nerves to the nasal capsules. Below the olfactory foramen is an *optic foramen* (II.), and at this point, in the dried skull, the two orbits are placed in communication by a hole. The oculomotor and pathetic nerves have exit by special small foramina near the optic, the fifth and sixth by a larger aperture behind the ali-sphenoid. The eighth nerve pierces the inner side of the auditory capsule, and, just in front of it, there is a small foramen for the seventh. Behind the tympanic cavity there is a small opening on either side at the posterior angle of the basi-temporal for the ninth, tenth, and eleventh (IX. and X.), while the twelfth passes out by a small *condylar foramen* situated in the ex-occipital near the condyle (XII.)

The *facial* part of the skull consists of the nasal capsules and jaws. The nasal capsules contain a good deal of cartilage, and are separated by a cartilaginous *nasal septum*, which is a continuation of the mesethmoid. A scroll-like fold, the *turbinal*, projects from it on either side. Below this is a slender *vomer* (*v*), just in front of the basi-sphenoidal rostrum. The capsules are partly roofed in by the *nasals* (*na*), which unite with the frontals behind, and are deeply notched in front. The notches partly bound the external nares.

The margin of the upper jaw is formed in front by the *pre-maxillæ* (*p-mx*), which also bound in part the nasal capsules, and possess upwardly and backwardly directed *nasal processes*, and backwardly directed *palatine processes*, which help to support the roof of the mouth. The pre-maxilla on either side passes back into a delicate rod-like *maxilla* (*mx*), from the anterior end of which a flat *maxillo-palatine process* (*mx.p*) projects towards the middle line. The maxilla fuses behind with a styliform *jugal* (*j*). These two last bones form the greater part of a sub-orbital bar, which is completed behind by a *quadrato-jugal* (*q-j*), the rounded posterior end of which is united by a fibrous band with the *quadrate* (*qd*). This is a short thickened bone, movably articulated at one end by two convex surfaces with the squamosal and pro-otic, while the other presents a transverse articular condyle for the mandible. Upon the ventral surface of the skull an X-shaped structure is formed by four bones, pterygoids behind and palatines in front. The *pterygoid* (*pt*) articulates behind with a facet on the quadrate, in front with a facet on the side of the rostrum, at its base. When the facial part of the skull is moved up and down, the pterygoids readily slide forwards and backwards on these smooth facets. The *palatine* (*pl*) is a flattened rod, broadest behind, where it meets its fellow and the pterygoid, and tapering to a point in front, where it fuses with the maxillo-palatine process.

*Mandibular Arch.**—The proximal part of this is formed by the *quadrate* (*qd*) on either side, to which one half or ramus of the mandible is articulated. This is almost straight, and anteriorly unites with its fellow in a median symphysis. The axis of the ramus is formed by Meckel's cartilage, which persists, more or less, throughout life, and is ossified proximally into the *articular* (*ar*), which is jointed on to the quadrate. *Angular* (*an*) and *supra-angular* (*s-an*) elements ensheath the ramus below and above in its proximal half, the latter being produced above into a small *coronoid process*, while the distal half is covered ventrally and externally by the *dentary* (*d*), internally by the *splenial*.

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* The *pterygoid* and *palatine* are a forward outgrowth of this arch.

Hyoid Arch.—The proximal end of this is formed by the *columella* (B), which serves the same purpose as that of the Frog. Its inner end is bony and expanded into an oval plate (*pl*) fitting into the fenestra ovalis, while its outer cartilaginous end is firmly fixed to the inner side of the tympanic membrane. The "hyoid apparatus" (C) consists of the *body* of the hyoid, supporting the base of the tongue and *anterior* and *posterior cornua*. The body is composed of three median pieces:—(*a.*) A cartilaginous *glosso-hyal* (*g-hy*), shaped like an arrowhead, from which the short *anterior cornua* (*a.c*) also of cartilage, diverge backwards; (*b.*) a short bony *basi-hyal* (*b-hy*); and (*c.*) a styliform bony *basi-branchial* (*b-br*). Between (*b*) and (*c*) the slender *posterior cornua* (*p.c*) diverge backwards and upwards. Each posterior cornu is three-jointed, the end-joint being cartilaginous.

The basi-branchial and posterior cornua represent the *first branchial arches.*

(*b.*) **Vertebral Column and Ribs.**—The vertebral column is divided into *regions*, arranged as follows:—

	No. of vertebræ.	
1. *Cervical*,	13 or 14	Free.
2. *Thoracic*—		
(*a*) Anterior,	4	Fused.
(*b*) Posterior,	1	Fused to form "*Sacrum.*"
3. *Lumbar*,	2 or 3	
4. *Sacral*,	4 or 3	
5. *Caudal*—		
(*a*) Anterior,	6	
(*b*) Middle,	6	Free.
(*c*) Posterior,	Several	Fused to form *ploughshare* bone.

The *cervical* vertebræ (E, 1-5) are those supporting the neck. Each is made up of two parts:—(*a.*) An elevated *centrum* (*c*), articulating with neighbouring centra by saddle-shaped surfaces which confer great flexibility. From the ventral side of the centrum a median flattened *hypapophysis* (*hy*) comes off. (*b.*) A *neural arch*, produced dorsally into a plate-like *neural spine* (*n.sp*), and connected with adjacent arches by *præ-* and *post-zygapophyses* (*a-z and p-z*), in the same way as in the Frog. *Intervertebral foramina* are left between the arches for the transmission of the spinal nerves.

The *last* cervical vertebra possesses a strong *transverse process* running out from either side of the neural arch. This vertebra bears a pair of *cervical ribs* (*compare E*, 6). Each of these is a small curved bone (*r*), with a forked proximal end attached to the vertebra, and a free distal end. From its hinder edge a small flat *uncinate process* (*un*) runs back. The two limbs of the forked end terminate in articular projections termed *head* (capitulum) (*cp*) and *tubercle* (*tb*). The former articulates with a small *capitular facet* on the side of the centrum near its front end, the latter with a similar *tubercular facet* on the under side of the transverse process. The last vertebra but one also bears free ribs, these, however, are devoid of tubercles and uncinate processes.

In the remaining vertebræ (except the first two), the *cervical ribs* are very short, and completely fused with the transverse process and centrum (*i.t*), an aperture being left, however, which, with those of the other vertebræ, forms the *vertebrarterial canal* (*v-c*) in which certain soft structures run. These fused ribs, with the transverse processes, neural spines, and hypapophyses diminish in size from behind forwards throughout the cervical region.

The *first* and *second* vertebræ, *atlas* and *axis*, are very small and possess no ribs nor transverse processes. The atlas (1) is a ring, without anterior zygapophyses. Over its centrum's upper surface a small peg, the *odontoid process* (2, *o.p*), projects from the front end of the centrum of the axis (2). The occipital condyle fits into an articular pit formed above by the odontoid process, and below by the atlas-centrum.

The odontoid process is at first a distinct bone. It is part of the atlas-centrum which fuses with that of the axis.

The *thoracic vertebræ* bear free ribs, and the commencement of the series is marked by the first vertebra (6) bearing ribs which unite ventrally with the sternum. The four anterior vertebræ are closely united with one another by their centra and the processes of their arches. The thoracic ribs are made up of two segments, one, the *vertebral rib* (*r*), similar in character and mode of attachment to the last cervical rib, the other, *sternal rib*, articulated distally, with a facet on the sternum (Fig. 132, A, *r*). The "*sacrum*" (D) of the adult bird is made up of vertebræ belonging to four regions closely fused together. The single *thoracic* vertebra (*t*, 5) is easily recognised by its rib (*r*). It possesses a large bilaminar hypapophysis, and its stout transverse processes abut against the ilia. The *lumbar* (*l*) vertebræ have short and strong, the *sacral* (S), lamellar transverse processes, while the first *caudal* (*c*, 1) possesses a ventral caudal rib as well as a dorsal transverse process.

The *free caudal* vertebræ are small, and their transverse processes flattened (D′, *c*′).

The *ploughshare bone* (D′, *p-st*) is a laterally flattened plate, bent up sharply on the rest of the vertebral column.

(*c.*) **Sternum** (Fig. 132, A).—This is a very broad, plate-like bone, concave above, supporting the ventral wall of the thorax and part of the abdomen. It is produced in front into an obtuse process, the *manubrium*, and behind, into a narrow plate, the *middle xiphoid process* (*x.p*). At the sides are paired *internal* and *external xiphoid processes* (*x.m* and *x.a*). Between the xiphoid processes are membrane-filled spaces. Those between the middle and internal processes may be bridged over by bone posteriorly (*as in Fig.* 132). On either side of the front of the sternum there is an excavation for the end of the coracoid, and behind this the *costal process*, which is the front end of the *costal border*. This bears four facets for the articulation of the external ribs (*r*). The ventral side of the sternum is produced downwards into a prominent vertical plate, the *keel* (*k*), which is deepest in front.

(2.) *Appendicular Endoskeleton.*—The long bones possess *epiphyses*, as in the Frog.

(*a.*) **Fore-Limb**—*Shoulder-girdle* (Fig. 132, A).—The *scapula* (*sc*) is a backwardly-directed, blade-like bone, united closely in front with a rod-like *coracoid* (*co*), the other end of which articulates with the sternum. These two bones make with one another an acute angle, open behind, and the *glenoid cavity* (*gl*) is situated at this point of union. In front of this the slender *clavicle* is attached, which curves backwards and downwards, and unites with its fellow in the middle line (*f*) to form the *furcula* ("merry-thought").

The union is effected through the intermediation of a small *interclavicle*. This forms in the Fowl a small, laterally flattened disc.

Free-Limb (Fig. 132, B).—The *humerus* (*h*) possesses a proximal *head* (*hd*) for articulation with the glenoid, and a distal, pulley-like *trochlea*, which presents preaxial and postaxial articular surfaces for the radius and ulna. Near these are small elevations, the radial and ulnar *condyles*, while close to the head there are similarly situated *greater* and *lesser tuberosities* (*r.t* and *u.t*), preaxial and postaxial respectively. Two distinct bones, radius (*r*) and ulna (*ul*), support the antebrachium. The preaxial *radius* is straight and slender, articulating with the trochlea proximally by a small excavated head, and distally with the carpus by a convex surface. The postaxial *ulna* is relatively stout, with a curved shaft concave to the radius, a proximal *sigmoid cavity*, for articulation with the trochlea, and a distal convex surface for articulation with the carpus. The proximal end is produced beyond the sigmoid cavity into an *olecranon process*.

The *carpus* is made up of two small bones, the *radiale* (*ra*) and *ulnare* (*u*), which articulate with the radius and ulna respectively. First, second, and third *metacarpals* are present, closely united proximally. The first (I.) is small, and projects but little beyond the fused part. The second (II.) is long and stout, and the third (III.) long and slender. The three digits are completed by *phalanges*, the first (1) and third (3) possessing a single small one, while two large phlanges (2 and 2′), the proximal one much flattened, terminate the second digit.

(*b*.) **Hind-Limb**—*Hip Girdle* (Fig. 131, D and D′).—Each half, or *os innominatum*, is separate from the other, and made up of three elements, ilium, ischium, and pubis, all three of which contribute to the formation of the *acetabulum* (*ac*), a rounded cup, not floored by bone, on the outer side of the girdle. The large *ilium* (*il*) extends forwards and backwards above the acetabulum. It meets and fuses with the anterior ends of the ischium and pubis to bound the acetabular cavity, above which it presents a smooth surface, the *anti-trochanter* (*an-t*). The "sacrum" is closely connected with the inner concave surface of the ilium.

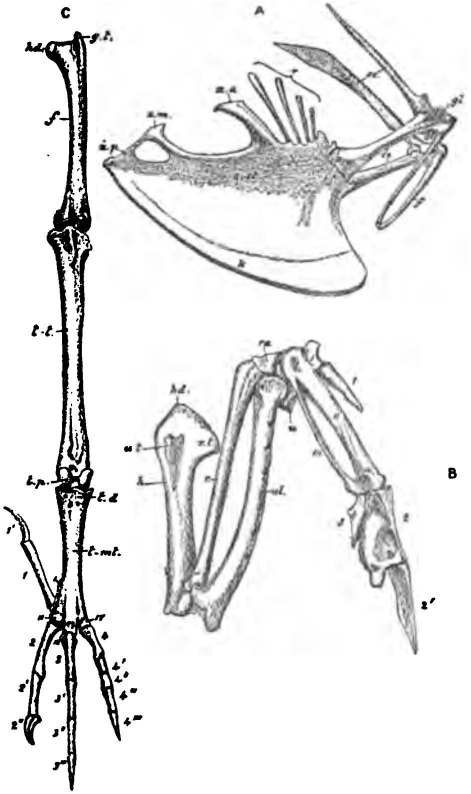

Fig. 132.—Endoskeleton of Pigeon.—A, Sternum and shoulder-girdles; *c.st*, corpus sterni; *k*, keel; *x.a*, *x.m*, *x.p*, external, internal, and middle xiphoid processes; *r*, sternal ribs; *co*, coracoids; *sc*, scapulæ; *f*, furcula; *gl*, glenoid cavity. B, Left Wing—*h*, humerus; *hd*, head of ditto; *r.t* and *u.t*, radial and ulnar tuberosities; *r*, radius; *ul*, ulna, showing scars left by quills; *ra*, radiale; *u*, ulnare; I.-III., metacarpals; 1-3, phalanges. C, Left Leg (patella gone, fibula not seen)—*f*, femur; *hd*, head; *g.t*, great trochanter; *t-t*, tibio-tarsus; *t.p*, proximal part of tarsus; *t.d*, distal part of tarsus; *t-mt*, tarso-metatarsus; I.-IV., metatarsals; 1-4, phalanges.

The *ischium* (*is*) is a flat rod running back from the acetabulum parallel to the lower edge of the ilium, beyond which it extends. The interspace is bridged over by bone, except for a space in front which forms the *ilio-sciatic foramen* (*i-s.f*). The *pubis* (*pb*) is a slender rod which, in the acetabulum, fuses with the ilium and ischium. It runs back below the latter, the *obturator fissure* (*ob*), separating the two, and extends for some distance behind it. A wide space separates the pubis and ischia of opposite sides.

Free Limb (Fig. 132, C).—The *femur* (*f*) articulates with the acetabulum by a preaxial *head* (*hd*) at right angles to the shaft, while its proximal end is terminated by a facet which works against the anti-trochanter, and on the postaxial side of which is a considerable elevation, the *great trochanter* (*gt*). The pulley-like distal end of the femur is formed of two articular *condyles*, a preaxial and a postaxial. The main bone of the *crus* is the preaxial *tibio-tarsus* (*t-t*) with which the small postaxial *fibula* is partly fused. The tibio-tarsus is a stout bone, much longer than the femur, for the articulation of which its proximal end presents two concavities. Its shaft exhibits a dorsal *cnemial crest*, and its distal end is pulley-shaped, and possesses two *condyles*. The *fibula* is a small postaxial rod which fuses distally with the tibio-tarsus. Proximally it fits into a pit in the postaxial condyle. In front of the knee-joint, formed by the junction of femur, tibio-tarsus, and fibula, there is a small irregular bone, the *patella*.

In the adult there is no separate *tarsus*, but in the embryo it is represented by two cartilages, the proximal of which unites with the preaxial tibia and forms the distal end of the tibio-tarsus (*t.p*), while the distal fuses with the metatarsus (*t.d*). The ankle-joint is thus between the two tarsal elements, and is said to be *mesotarsal*—*i.e.*, in the middle of the tarsus.

Four *digits* are present—first, second, third, and fourth. The *metatarsals* of the three last fuse with the distal part of the tarsus to form the *tarso-metatarsus* (*t-mt*). This is a rod of bone, the proximal (tarsal) end of which (*t.d*) presents concavities for the condyles of the tibio-tarsus, while its distal end possesses three very distinct pulley-like surfaces (II., III., IV.) for the three corresponding metatarsals. The small first metatarsal (I.) is attached to the preaxial side of this end. The four *digits*, of which the first or *hallux* is directed backwards, are completed by 2, 3, 4, and 5 *phalanges* (1-4) respectively. The terminal phalanges support claws.

Histology.—The *cartilage* is much like that of the Frog in minute structure. The *bone* is extremely spongy, but possesses a very firm, dense, outer layer, and in the skull a similar inner layer as well. The compact portions contain narrow *Haversian canals* for blood-vessels, united together by numerous cross-branches, and taking a longitudinal direction in the long bones. Around these canals concentric lamellæ of bone are arranged, and, in correspondence with this, the *lacunæ* with their *bone-corpuscles* are arranged, as seen in cross-section, in concentric circles (Haversian systems).

4. **Digestive Organs** (Fig. 133).—The *mouth* is bounded by the horny margins of the beak (*b*). Owing to the double joint by which the mandible is connected with the skull, it can be opened very widely. Upon the roof of the *mouth-cavity* are two narrow slits, the *internal nares* (*p.n*), largely overlapped by folds of mucous membrane. Behind them is a small median *Eustachian aperture*, and posterior to this the end of the roof is marked by a backwardly directed fringe. The large *tongue* (*t*) attached to the floor of the mouth, has a sharply-pointed tip directed forwards. Its hinder part is produced backwards into fringed processes, behind which is the *glottis* (*gl*), a narrow slit, with edges also somewhat fringed. The back part of the mouth-cavity, or *pharynx*, is continued behind into a very long *œsophagus* (*œ*), for the most part with thin walls, which runs back on the ventral side of the neck to reach the thorax. In the posterior part of the neck it dilates into the *crop*, a very large bilobed sac, with extensible walls. Behind this the œsophagus narrows, and its walls are much thicker. It passes in the thorax into a small oval chamber, the *proventriculus*, of somewhat larger calibre, and with thick soft walls, upon the inner surface of which are a number of small rounded apertures, those of the *peptic glands*. The proventriculus opens, on the left side, into the dorsal border of the *gizzard*, a large rounded, somewhat flattened structure with extremely thick hard walls, the lining of which is horny. It contains numerous small pebbles and other foreign bodies which have been swallowed. A narrow tube, the *small intestine*, comes off from the right side of its dorsal border, forms

a U-shaped loop, the *duodenum*, and, after making several loops and coils, merges into the short, straight, *large intestine*. The junction between the two is marked by a pair of small projections, the *intestinal cœca*.

These are very large in the Fowl.

The lining of the small intestine is raised into innumerable delicate thread-like processes, the *villi*, which gradually die away posteriorly and are replaced by longitudinal ridges.

The large intestine opens behind into a small *cloaca* (*cl*) which opens externally by the *cloacal aperture*. The cloaca is divided by inwardly projecting folds into three compartments, internal, middle, and external (Fig. 134, *cl*, *cl′*, and *cl″*). The first receives the large intestine, the second the urogenital ducts, while into the dorsal wall of the third a small thick-walled pouch, the *bursa Fabrici*, opens in young birds.

The lining of the large intestine and cloaca is smooth.

The *liver* is a large, brown organ, lying on the ventral side of the body, and presenting depressions above and in front into which the heart, duodenum, and gizzard fit. It is divided into *right* and *left lobes* (*l.l*), of which the first is the larger. There are two *bile-ducts* (×, ×), the left short and wide, running into the duodenum near its commencement, while the right, long and narrow, opens into its distal limb near the beginning of its distal third. There is no *gall-bladder*.

A gall-bladder is present in the Fowl. The bile and pancreatic ducts are also arranged differently.

The *pancreas* (*p*) is a compact, elongated body, lying in the loop of the duodenum, and sending three *pancreatic ducts* (*, *, *) into its distal limb. Two of these are short, arise from the middle of the pancreas, and open close together proximally to the right bile-duct. The third is longer, and runs from the anterior end of the pancreas into the duodenum near its termination.

As in the Frog, the alimentary canal is suspended from the dorsal wall of the body-cavity by mesenteric folds. The membranous lining of the abdominal region (which, however, is quite continuous with that of the thorax) is the *peritoneum*. This closely lines the dorsal side of the cavity before leaving its walls

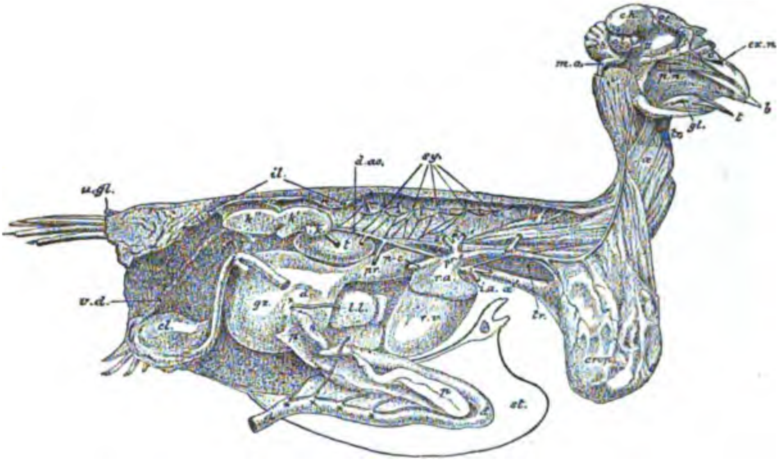

Fig. 133.—General Dissection of Male Pigeon.—*c*, Cere, close to which is external naris, *ex.n.* ; *u.gl*, opening of uropygial gland ; *il*, cut edge of ilium; *st*, keel of sternum. A large part of this bone has been removed together with ribs. *b*, Beak ; *t*, tongue ; *p.n*, internal nares ; *gl*, glottis ; *œ*, œsophagus, which swells into the crop in the middle of its course ; *pr*, proventriculus ; *gz*, gizzard ; *d*, duodenum. Most of ileum has been cut away, at *i* its junction with large intestine is seen. This point is marked externally by the intestinal cæca, one of which is shown ; *cl*, cloaca ; *l.l*, placed on left liver-lobe at point where right lobe was removed ; ×, ×, placed on points where bile-ducts enter duodenum ; *p*, pancreas ; ***, placed on points where the pancreatic ducts enter duodenum ; *r.a*, right auricle of heart, into which the cavals run ; *pr-c*, right precaval, formed by the union of (*ju*) jugular and subclavian, the short vessel just over *pr-c*, which the brachial (1) and pectoral (2, 2′) veins combine to form ; *p-c*, postcaval, the other cut end of which is close to *t ; r.v*, right ventricle ; *i.a*, right innominate artery bifurcating into common carotid above, and subclavian, the latter at once dividing into brachial (above) and pectoral (below). The dorsal aorta (*d.ao*) is seen running back from heart. The cut end of the cœliac artery is just above *pr*, and that of the anterior mesenteric to the right of *t ; tr*, trachea ; *k*, *k*′, *k*″, anterior, middle, and posterior lobes of right kidney cut through ; *v.d*, right vas deferens, along inside of which right ureter runs ; *t*, left testis, the right is removed ; *ol*, placed over olfactory lobe, and olfactory nerve which runs forwards from it ; *c.h*, cerebral hemisphere ; *o.l*, optic lobe ; *cb*, cerebellum ; *m.o*, medulla oblongata. II., Optic nerve, just above which is optic tract ; *sy*, right sympathetic ganglia of thorax, between which are cut ends of ribs. The ganglia are connected by double commissures, which, with connected nerve branches, are represented dark.

to form mesenteric folds, so that a large subvertebral lymph-sinus is not formed, as in the Frog.

Histology.—The wall of the alimentary canal is made up of the usual three coats—mucous membrane, muscular, and serous. The *mucous membrane* possesses an epithelial lining varying in the different parts of the canal. That found in the mouth-cavity and part of the œsophagus is *stratified squamous epithelium*, and that lining the crop *glandular.* The lower parts of the œsophagus, the proventriculus, and the intestines are lined by *simple columnar epithelium*, continued into the simple tubular *peptic glands* of the second, and there becoming glandular. *Glands of Lieberkühn* are present in the small intestine. The epithelium of the gizzard secretes a thick horny cuticle.

The *muscular coat* varies very much in thickness, and typically consists of two layers, an external circular and an internal longitudinal. It is immensely thickened in the gizzard, and has there a complicated arrangement.

The *serous coat* is a connective-tissue layer present from the proventriculus backwards, and formed by the investing mesentery.

The *liver* and *pancreas* present no important deviations from the structure of the same organs in the Frog (*p.* 242).

5. Circulatory Organs.—*Blood* and *lymph systems* are present, and well-developed.

(1.) **Blood System.**—The bright red *blood*, which coagulates very quickly, is made up of *plasma*, with *white* and much more numerous *red corpuscles.* The latter are small, flattened, and oval, with ends somewhat pointed. They possess nuclei.

The large conical *heart* (Fig. 133), contained in its *pericardium*, lies in the anterior part of the thorax, and its backwardly directed apex fits into an excavation in the liver. Its base is occupied by the dark thin-walled *right* (*r.a*) and *left auricles*, its apex by the thick-walled *right* (*r.v*) and *left ventricles*, of which the latter is the firmer, and alone reaches the extreme apex. The cavities of the auricles are separated by a thin *auricular septum*, upon which is a depression, the *fossa ovalis*, where the septum is thinnest. Within the right auricle are the three openings of the caval veins, that of the postcaval being guarded by a muscular flap, the *Eustachian valve*, and, posteriorly, the crescentic *right auriculo-ventricular opening* leading into the right ventricle. From the right side of this opening a muscular flap, the *right auriculo-ventricular valve*, projects into the ventricular cavity, to the walls of which it is united by fibrous cords, the *chordæ tendineæ*. The right ventricle is separated from the left by the *ventricular septum*, which bulges into its cavity, the walls of which are raised into muscular ridges, *columnæ carneæ*. The *pulmonary artery*, which arises from this division of the heart, has its origin guarded by three *pulmonary semilunar valves*. Within the left auricle, dorsally, is the small opening of the pulmonary veins, and, posteriorly, the rounded *left auriculo-ventricular opening*. This is guarded by a *mitral* or *bicuspid valve*, made up of two membranous flaps, which are placed in the cavity of the left ventricle, and connected by chordæ tendineæ with the *papillary muscles*. These are conical elevations which may be considered as modified columnæ carneæ. The aorta arises from the anterior end of the left ventricle, and its origin possesses three *aortic semilunar valves*.

Arteries.—A single aortic arch is present, the *aorta*, which runs forward a little, curves round to the right, and then, reaching the middle dorsal line, becomes the *dorsal aorta* (*d.ao*). From the curved part, or *arch of the aorta*, large *right* (*i.a*) and *left innominate arteries* are given off close to the heart, after which the calibre of the aorta diminishes considerably. Each innominate divides very quickly into *common carotid* and *subclavian arteries*. The common carotid runs along the neck, soon giving off the *vertebral artery* (which supplies the brain and spinal cord, and occupies the vertebrarterial canal), and, at the angle of the jaw, divides into *internal* and *external carotids*. The former supplies the brain, the latter the head generally. The *subclavian* divides almost at once into the small *brachial* and large *pectoral* arteries, which respectively supply the wing and muscles of the chest. The dorsal aorta gives off an unpaired *cœliac artery*, the branches of which run to the proventriculus, gizzard, spleen, duodenum, pancreas, and last loop of the small intestine; while, slightly behind this, an unpaired *anterior mesenteric artery* comes off, which supplies the rest of the small intestine. Still further back the small *anterior renal arteries*, for the anterior kidney-lobes; the *femoral arteries*, for the extensor muscles of the thigh; and the *sciatic arteries*, for the flexor muscles of the thigh and for the rest of the hind-limb, are given off in succession. Branches of the sciatic, the *middle* and *posterior renal arteries*, supply the corresponding kidney-lobes. Just behind the kidneys the dorsal aorta gives off an unpaired *posterior mesenteric artery* to the large intestine and cloaca, and paired *internal iliac arteries* to the hinder part of the pelvis, and then runs, as the *caudal artery,* into the tail.

The *pulmonary artery* arises from the right ventricle, and soon divides into right and left branches for the right and left lungs.

Veins.—These may be dealt with under the headings of caval system, hepatic portal system, and pulmonary veins.

Caval System.—There are two precavals and a postcaval, all opening into the right auricle. Each *precaval* (*pr-c*) is a large, short vein, formed by the union of three trunks—jugular (*ju*), brachial (1), and pectoral (2, 2′). The *jugular* runs back from the base of the head (where it is united by a cross-trunk with its fellow), along one side of the neck, and not far from its union with the other two trunks, receives the *vertebral vein* (*just above ju*). It brings back blood from one side of the head and neck. The *brachial* and *pectoral veins* return blood from the wing and chest-muscles of one side.

The *postcaval* (*p-c*) is a large vein, formed just in front of the kidneys, by the union of two *iliac veins,* and running through the liver, from which it receives two *hepatic veins,* to the heart. The *iliac* on either side commences between the anterior and middle kidney-lobes where the *femoral vein,* bringing back blood from the greater part of the hind-limb, unites with the *hypogastric vein* to form it. The latter traverses the substance of the kidney, behind which it is connected with its fellow by a cross-branch, that receives the *caudal vein* from the tail, and *internal iliac veins* from the pelvis, and is also united with the hinder end of the *posterior mesenteric* vein. The *sciatic vein* carries blood from the hinder part of the leg into the hypogastric, at the junction of the middle and posterior kidney-lobes. These lobes return their blood by a large superficial *renal vein* to the iliac vein, which also receives a small vein from the anterior lobe.

Hepatic Portal System.—This is the only portal system present in the Pigeon, and is entirely made up of vessels from the alimentary canal and spleen. Into the left liver-lobe two small *left gastric veins* take blood from the left side of the gizzard, while the large *portal vein* divides into two branches, one for each liver-lobe. This vein is formed by the union of three others—*gastro-*

duodenal, returning blood from the right side of the gizzard, duodenum, pancreas, and last loop of the small intestine; *anterior mesenteric*, from the rest of the small intestine; and *posterior mesenteric* from the large intestine and cloaca. (The hypogastric veins receive part of their blood from this vessel.) The spleen pours its blood directly into the portal trunk.

One or two short *pulmonary veins* from each lung unite together and open by a single aperture into the left auricle on its dorsal side.

(2.) **Lymph System.**—This mainly differs from that of the Frog (*p.* 247) in the absence of distinct lymph-hearts, and the greater definiteness of the lymphatic trunks. These open into two delicate tubes, the *thoracic ducts*, lying just beneath the vertebral column in the thoracic region, which communicate with the veins at the junction of the jugular and subclavian on either side. Two small oval bodies, the *cervical lymphatic glands* are found at the base of the neck.

A small red *spleen*, oval in shape, is attached to the right side of the proventriculus.

Histology.—Substantially the same as in the Frog.

6. **Respiratory Organs** (Fig. 133).—The *glottis* (*gl*) leads into a small chamber, the *larynx*, the walls of which are supported by several cartilages, and which is the commencement of the *windpipe* or *trachea* (*tr*), a long tube which runs along the neck to the thorax. It lies ventral to the œsophagus in its first and last parts, but is pushed to the left side in the region of the crop. Numerous firm rings, bony ventrally, cartilaginous dorsally, surround and support the trachea, which bifurcates in the thorax into a right and a left *bronchus*, one going to each lung. They are supported by rings. At the point of bifurcation is situated the *syrinx*, which is here the organ of voice.

The end of the trachea and commencements of the bronchi enclose the *tympanum* or syringeal cavity. Into this an elastic fold, the *membrana semilunaris*, projects from the point of bifurcation, and is supported by a slender bar of cartilage, the *pessulus*, running dorso-ventrally. The inner side of each bronchus, at its commencement, is membranous, and forms the *membrana tympaniformis interna*. Special muscles are connected with the syrinx.

The *lungs* are spongy bodies, dark-red in colour, which lie in the anterior part of the thorax. They are closely attached to the ventral side of the vertebral column and ribs, and, when removed, their dorsal surfaces are seen to possess corresponding depressions. A thin membrane, the *pleura*, continuous with the peritoneum, closely covers their ventral surface. The bronchus which runs to either lung enters it, becomes membranous, and, after dilating into a vestibule, runs towards the external side of its posterior end, bifurcating into two *secondary* bronchi. Other secondary bronchi come off from the vestibule. All these tubes are placed near the ventral surface of the lung, the dorsal part of which organ is mainly made up of their branches, delicate tubes with blind endings.

Closely connected with the lungs are a number of thin-walled *air-sacs*. The secondary bronchi open upon the surface of the lungs into these. On either side of the body, in the abdominal region, between the kidneys and the intestines, there is a large *posterior air-sac*, communicating with the hinder end of the lung. In front of this are two pairs of intermediate air-sacs, situated on the ventral side of the body-cavity. The *posterior intermediate air-sacs* overlap the hinder part of the lungs, and communicate with them by openings close to those of the posterior sacs, while the *anterior intermediate air-sacs* are situated ventral to the anterior two-thirds of the lungs, and open into them near the middle of their length. In the region of the clavicle a large, unpaired *interclavicular air-sac* is present (formed by the fusion of two *sub-bronchial air-sacs*), communicating with either lung by an aperture near the entrance of the bronchus. This air-sac is bilobed, and each lobe passes out of the body-cavity near the origin of the wing to communicate with the hollow shaft of the humerus, while dorsal to it there is a small *prebronchial air-sac*, connected with the anterior end of the lung.

Histology.—The most important point to be noticed is the finer structure of the delicate tubules making up the greater part of the lungs. The walls of these are raised up internally into intersecting ridges, which form a complicated honeycombing, traversed by networks of capillaries, and covered by simple squamous epithelium.

The epithelium lining the branchi and trachea is largely ciliated.

7. Excretory, and 8. Reproductive Organs (Fig. 134).—The reddish-brown *kidneys*, covered ventrally with peritoneum, are situated just behind the lungs, and closely applied to the under side of the ilia and "sacrum." Each possesses three lobes, anterior (*k*), middle (*k'*), and posterior (*k''*). Between the two first, on the ventral side, a small thin-walled *ureter* (*u*) arises, which runs to the middle division of the cloaca, into the dorsal side of which it opens (*u'*).

Male Reproductive Organs (Figs. 133 and 134, B).—The *testes* (*t*) are two oval, whitish bodies, situated ventral to the kidneys, and near their anterior ends. They are invested in peritoneum, and held in place by *mesorchia*. From the inner side of each an opaque white tube, the *vas deferens* (*v.d*), repeatedly and sharply bent from side to side, runs on the outer side of the corresponding ureter to the cloaca, dilating at its end into a *vesicula seminalis* (*v.s*), and opening on a small *genital papilla* (*g.p*) placed just external to the opening of the ureter.

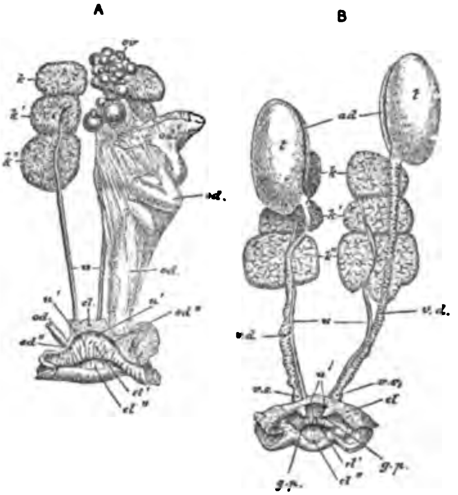

Fig. 134.—UROGENITAL ORGANS OF PIGEON.—A, Female; B, male; *k*, *k'*, *k''*, anterior, middle, and posterior lobes of kidney; *u*, ureters; *u'*, openings of ditto; *cl*, *cl'*, and *cl''*, internal, middle, and external divisions of the cloaca, which has been cut through on its ventral side and opened out; *t*, testes; *v.d*, vasa deferentia; *v.s*, vesiculæ seminales; *g.p*, genital papillæ, on the end of which are the male genital openings; *ov*, ovary; *od*, oviducts (right a mere rudiment); *od'*, funnel of left oviduct; *od''*, openings of oviducts into cloaca; *ad*, adrenals.

Female Reproductive Organs (Fig. 134, A).—These are only developed on the left side. The *ovary* (*ov*) is a very irregular body (similarly situated to the testes), from the outer surface of which globular ova of various sizes project, enclosed in follicles. It is covered by peritoneum, which forms a *mesovarium*. The *oviduct* (*od*) is a thick-walled convoluted tube, communicating with the body-cavity at one end by a delicate membranous funnel (*od'*), situated near the ovary, and at the other entering the cloaca by a large aperture (*od''*) external to the opening of the left ureter. The *right* oviduct may be represented by a short blind tube having a similar situation (*od, other side*).

The cloaca is larger in the female.

The *adrenals* (Fig. 134, B, *ad*) are small elongated bodies, of yellowish colour, closely connected with the origin of the iliac vein on either side.

Histology.—The *uriniferous tubules* do not communicate by nephrostomes with the body-cavity, nor are they anywhere ciliated. Bowman's capsule, with its glomerulus, passes into a dilated glandular portion, which, after a somewhat convoluted course, is succeeded by a narrow looped part. The terminal portion of the tubules unite again and again to form the ureter (*comp. Fig.* 152).

The *testis* is made up of a large number of much-convoluted seminiferous tubules formed by the continued branching of the vas deferens. The tubules are lined by germinal epithelium, the cells of which, *spermatospores*, produce *spermatozoa*, with cylindrical heads and motile tails.

The *ovary* consists of a connective-tissue framework, the *stroma*, richly supplied with blood-vessels. The ova are contained in *Graafian follicles*, lined by *follicular epithelium*, which is again invested by the stroma.

These *ovarian ova* are, when ripe, yellow spheres rather less than an inch in diameter. Such an ovum (*comp. Fig.* 136) is covered by a delicate *vitelline membrane* (DM), within which is the vitellus, containing a germinal vesicle placed close to the surface. That part of the vitellus in which the germinal vesicle is imbedded, the *germinal disc* (*in position of Bl*), is a small lens-shaped mass of clear protoplasm, while the rest is mainly made up of food-yolk, through which protoplasm is sparingly diffused. The yolk is of two kinds—*yellow* (GD), composed of granular spheres, and *white* (WD), formed of smaller spheres enclosing highly refracting spherules. The yellow yolk is more abundant, while the white yolk is arranged in a flask-shaped mass running from the germinal disc to the centre of the ovum, and several thin lamellæ concentric to this.

Polar cells or their equivalents are probably formed (*comp. Fig.* 93).

The *oviducts* possess muscular walls, and are lined by glandular and ciliated epithelium.

9. **Muscular System.**—The muscles may be classified as in the Frog (*p.* 254), but their arrangement is more complicated. The presence of air-sacs largely increases the surface for attachment of the muscles of flight. The most important of these take origin in the sternum and its keel, and are inserted into the humerus.

Histology.—Both unstriated and striated muscle are present, as in the Frog, and their structure (*comp. Figs.* 115 and 153) and distribution are substantially the same.

10. **Nervous System** (Fig. 133)—(1.) **Cerebro-Spinal Axis.**—Investing membranes are present, pia mater, arachnoid, and dura mater, but both brain and spinal cord closely correspond in shape to the cavities in which they are placed.

The **brain** is large and rounded. As before (*p.* 255), it may be divided into fore-, mid-, and hind-brains:—(*a.*) *Fore-brain.*—The *thalamencephalon* contains a large slit-like *third ventricle*, bounded by the *lamina terminalis* in front, and the *optic thalami* at the sides (united behind by a *posterior commissure*), while a stalked *pineal gland* is connected with its thin roof, and a *pituitary body* with the *infundibulum* formed by its floor. This part of the fore-brain is overlapped by the large smooth *cerebral hemispheres* (*c.h*). These are ovoid bodies closely applied to each other in the middle line, broadest behind and bluntly pointed in front. Each contains a large *lateral ventricle*, communicating with the third ventricle by a *foramen of Munro*, and having its floor raised into a considerable elevation, the *corpus striatum*. The two corpora striata are connected by the *anterior commissure* running in the lamina terminalis. A small pointed *olfactory lobe* (*ol*) is connected with the anterior end of each hemisphere, close to the middle line on the ventral surface, and it contains a small *olfactory ventricle*, continuous with the lateral ventricle.

(*b.*) *Mid-brain.*—The *optic lobes* (*o.l*) are very large. They are widely separated from one another, and situated laterally, but remain united by a dorsal *optic commissure.* Each contains a good-sized *optic ventricle*, which opens into the *Sylvian aqueduct.* This connects the third and fourth ventricles. Its floor is very thick, and formed by the *crura cerebri.*

(*c.*) *Hind-brain.*—The thickened and cylindrical *medulla oblongata* (*m.o*) possesses shallow *dorsal* and *ventral fissures.* The roof of the *fourth ventricle* is extremely thin. The *cerebellum* (*cb*) is a large rounded projection, flattened laterally, which overlaps the mid-brain and medulla. It is marked by deep transverse furrows, and on either side presents a small rounded elevation, the *flocculus.* The cerebellum is united with the medulla by a large cylindrical *peduncle* on either side.

Spinal Cord.—This is continuous in front with the medulla, a sharp ventral flexure marking their union, and tapers gradually back to the caudal region, exhibiting, however, considerable *brachial* and *lumbar enlargements* where the limb-nerves come off. *Dorsal* and *ventral fissures* are present, and a *central canal*, which in the lumbar enlargement expands into a *sinus rhomboidalis*, the lozenge-shaped roof of which is covered by pia mater only.

(2.) **Cranio-Spinal Nerves.**—There are twelve pairs of *cranial nerves*, the first ten of which correspond in origin and distribution to those of the Frog (*p.* 256). The *optic chiasma* is very large, and the *optic tracts* very wide. The (V.) *trigeminal nerve* arises by two roots, upon the larger of which is the *Gasserian ganglion.* Owing to the elongation of the neck, a very long course is taken by the (X.) *vagus* to reach the heart, lungs, &c. The (XI.) *spinal accessory nerve* is made up of fibres arising from the side of the spinal cord and medulla. It leaves the skull with the vagus, and supplies some of the neck-muscles. The (XII.) *hypoglossal* nerve corresponds to the first spinal of the Frog, and has a similar distribution, but it arises from the ventral surface of the medulla oblongata.

For the nerve exits *see p.* 283.

The *spinal nerves* arise by dorsal and ventral roots (the former ganglionated) from the spinal cord, and pass transversely outwards by the intervertebral foramina. They are named cervical, thoracic, &c., in the corresponding vertebral regions. The *brachial plexus*, from which the wing is supplied, is produced by the union of the last three cervical with the first thoracic. A *lumbar plexus* is formed by the last lumbar and first sacral nerves, and a *sciatic plexus* by the five succeeding nerves. These two plexuses supply the hind-limbs and their girdles.

(3.) **Sympathetic System** (Fig. 133, *Sy*).—The main part of this is a delicate ganglionated cord running close to the vertebral column on either side. The ganglia are connected by *rami communicantes* with the commencements of the spinal nerves. The anterior part of the cord on either side runs in the vertebrarterial canal, while the two unite behind in an unpaired ganglion (*ganglion impar*).

Histology.—The same elements are present as in the Frog, and their structure and arrangement are similar (*comp. Fig.* 124). There are, however, no bipolar ganglia in the sympathetic of the peculiar kind described on *p.* 260. The external part of the cerebellum is composed of grey matter, its internal part and peduncles of white matter.

11. Sense Organs.—(1.) **Tactile Organs.**—Many of the nerves ramifying in the skin terminate in oval *touch-corpuscles*, not flattened like those of the Frog.

(2.) **Gustatory Organs.**—*Gustatory cells*, supplied by the fibres of the glossopharyngeal nerve, are present in the hinder part of the tongue and roof of the mouth.

(3.) **Olfactory Organs.**—The *nasal sac* on either side, which communicates by an *external naris* with the exterior, and by an *internal naris* with the mouth-cavity, is partly lined by olfactory epithelium. This covers the projecting *turbinal* (*p.* 284), the rolled shape of which increases the surface. The olfactory nerve breaks up below the olfactory epithelium to supply the *olfactory cells*, of which it is largely made up (*comp. Fig.* 125).

(4.) **Auditory Organs.**—External, middle, and internal ears are present. The *external ear* consists of a short tube, the *external auditory meatus*, opening below and behind the eye. It is separated by the *tympanic membrane* from the *middle ear* or *tympanic cavity* (*p.* 261). This communicates with the mouth-cavity by an *Eustachian tube*, while the *columella* stretches across it, having one end attached to the tympanic membrane and the other inserted into the *fenestra ovalis*, below which is the *fenestra rotunda*. The *middle ear* is essentially composed of the *membranous labyrinth* (Fig. 135, B), enclosed in a somewhat larger cavity (filled with *perilymph*) of closely corresponding shape. This cavity is contained in the auditory capsule, and is surrounded by a thin, dense layer of bone, forming the *bony labyrinth*. The *utriculus* and *sacculus* (*compare p.* 262, *Fig.* 125) are ill-marked off from one another (*us*). With the former three *semicircular canals* are connected, arranged as in the Frog, with the exception that the posterior vertical takes an outward course, and crosses the horizontal before it dilates into an ampulla. A slightly curved tube, the *cochlea* (*c*), is connected with the anterior part of the sacculus. The membranous labyrinth contains endolymph with otoliths, and is lined by epithelium, patches of which, in the utriculus, sacculus, ampullæ, and cochlea are largely made up of *auditory cells* (*comp. Fig.* 125), connected with auditory nerve-fibres.

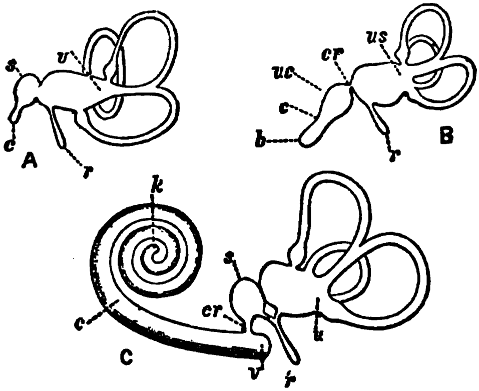

Fig. 135.—DIAGRAMS OF THE MEMBRANOUS LABYRINTH (from *Haddon*). Internal side of left labyrinth.—*B*, Bird. *C*, Mammal; *us*, utriculus and sacculus; *u*, utriculus; *s*, sacculus; *c*, cochlea.

(5.) **Optic Organs.**—The *eye* agrees in all essential particulars with the description on *p.* 264, but differs in certain points. The inner half of the eyeball is hemispherical, while its outer part is somewhat conical and terminated by the very convex *cornea*. Outside this last the *sclerotic* is strengthened by a circlet of small, flat *sclerotic plates* (Fig. 131, E, 7). The *crystalline lens* is flattened, and a vascular, pigmented, longitudinally plaited fold, the *pecten*, projects into the vitreous *humour* below the entry of the optic nerve.

The *accessory* parts connected with the eye are the three *eyelids* (*p.* 278), *conjunctiva*, two *glands*, and the *eye-muscles*. The glands are (1) the *Harderian gland* in front, and (2) the *lachrymal gland* behind and above. The eye-muscles are arranged much as in the Frog.

PHYSIOLOGY.

Very similar to that of the Frog.

1. **Nutrition.**—The food is of vegetable nature, and is temporarily stored up in the crop. The gizzard, in virtue of its horny lining and the contained stones, forms an efficient mill.

Circulation.—The two sides of the heart do not directly communicate, and therefore no mixing of blood occurs, as in the Frog. The impure blood from the body is poured into the right auricle by the caval veins, and passes into the right ventricle, by which it is forced to the lungs. Thence the oxygenated blood is returned to the left auricle, and, passing into the left ventricle, is pumped through the aorta to the body at large.

The movements of the heart are very vigorous. The auricles contract together, and their systole is followed by a ventricular systole, both ventricles contracting together. The auriculo-ventricular valves prevent the blood from passing back into the auricles, and the chordæ tendineæ prevent the valvular flaps from going too far. The chordæ would be slackened during the ventricular systole by the approach of the ventricular walls, were this not compensated for by the papillary muscles, which contract at the same time and pull the chordæ taut. The semilunar valves only allow blood to pass *out of* the ventricles.

2. **Destructive Metabolism**—(1.) **Respiration.**—The lungs are very immobile and take but little part in the respiratory movements. *Expiration* is effected by a contraction of the body-walls, by which the highly elastic air-sacs are compressed. *Inspiration* is passively effected by the elasticity of the body-walls, which expand and cause air to rush into the air-sacs. Owing to the presence of these, a large amount of air passes through the main passages of the lung. The *essential* part of respiration takes place in the small tubes making up the bulk of the lung, the walls

20

of which are raised into folds, and the air is kept pure in them by diffusion.

Respiration is very vigorous, in accordance with the rapid oxidation (metabolism) of the tissues. A great deal of heat results from this latter process, and the body is maintained at a very high temperature (103°-104° F.)

The organ of **voice** is here the syrinx.

(2.) **Excretion.**—The water and salts are strained off in Bowman's capsules, while the nitrogenous waste is excreted, mainly as *uric acid* ($C_5H_4N_4O_3$) by the glandular parts of the uriniferous tubules. The urine is semi-solid.

(3.) The **skin** performs excretory among other functions, water ("perspiration") evaporating from it.

3. Reproduction.—The cloacal chambers of the two copulating individuals are partially everted and the sperm passed into the oviduct. The ova burst out of their capsules into the body-cavity, and are taken up by the funnel of the oviduct. Before passing down very far, they are fertilized (Fig. 94) by the fusion of a single spermatozoon with each.

4. Contractility.—The air-sacs give the body a very large surface in proportion to its weight. This is of great importance for the attachment of the muscles of flight.

The specific gravity of the body is also diminished thereby, as also by the nature of the bones, and flight is thus indirectly aided.

5. Irritability and Spontaneity.—The most important advance upon the Frog is found in the large size of the *cerebral hemispheres*, and this is associated with increased intelligence. The large *cerebellum* has apparently the correlation of muscular movements for its main function.

It has been determined by experiment that the *semicircular canals* of the ear have to do with the perception of position in space. In this connection the fact that their planes are mutually at right angles deserves notice.

DEVELOPMENT.

The common Fowl has been most studied, and, as birds differ but little in their development, will be here described.

1. Early Stages.—The fertilized ovum, in passing down the oviduct, is covered by several structures secreted by its walls (Fig.

136). These are:—(1) The *white of the egg* (*EW*), mainly composed of semifluid proteid material, and containing a somewhat convoluted cord, the *chalaza* (*Ch*), at either end, partially extending from the ovum to (2) the double-layered *shell-membrane* (*S*) covered by (3) the *shell* (*KS*), formed of an organic matrix hardened by salts of lime. The entire egg is elongated, and broader at one end than the other. **Segmentation** (Fig. 137) is *unequal* and also *partial*, being confined to the germinal disc. It commences in the lower part of the oviduct, and by a succession of furrows, some at right angles and others parallel to the surface, the germinal disc is converted into a many-celled *blastoderm*. This is placed on one side of the ovum (Fig. 136, *Bl*), and always remains uppermost, the most favourable position for development, which requires a good deal of warmth, supplied in nature by the body of the hen. Before incubation (Fig. 138) the blastoderm consists of a superficial layer, one-cell thick, of columnar **epiblast** (*a*), and below this a more irregular thickened mass of *lower layer cells* (*b*), which are rounded, granular, and of larger size. Below them is a space (*f*), the earliest rudiment of the alimentary canal. The blastoderm is at first circular, and the more transparent central part, known as the *area pellucida*, is surrounded by a darker rim,

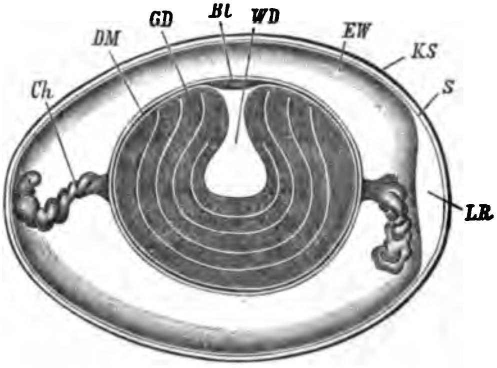

Fig. 136.—Diagrammatic Longitudinal Section Through Unincubated Hen's Egg (from *Claus*, after *Balfour* and *Allen Thomson*).—*Bl*, Blastoderm; *GD*, yellow yolk; *WD*, white yolk; *DM*, vitelline membrane; *EW*, "white;" *Ch*, chalazæ; *S*, shell membrane; *KS*, shell; *LR*, air-chamber.

the *area opaca* (*comp. Fig.* 140). If the egg is placed with its broad end to the right, the diameter of the blastoderm, which is to become the long axis of the embryo, will run *across* the egg, the *posterior* end being *towards* the observer.

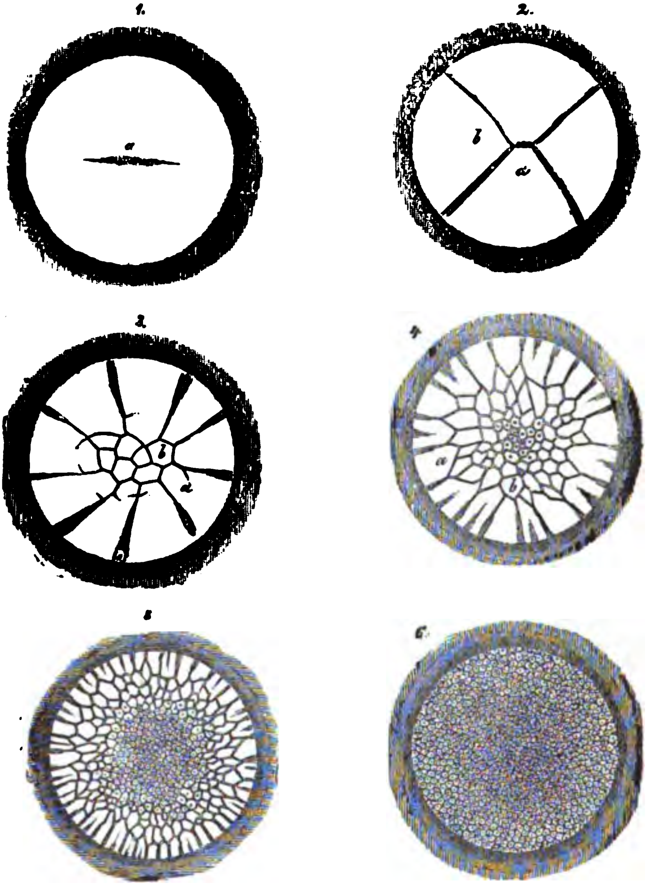

Fig. 137.—Surface Views to Show Segmentation in the Fowl's Ovum (from *Kölliker*, after *Coste*).—Segmentation commencing in 1, completed in 6.

It now remains to describe the formation of the hypoblast and mesoblast. These are first clearly differentiated in the *posterior* part of the blastoderm. Many of the lower layer cells here become much flattened and unite to form a thin membrane, the **hypoblast** (Fig. 139, *hy*). In the hinder part of the area pellucida an opaque longitudinal strip, the *primitive streak* (Fig. 140, *Pr*), appears. This is a local thickening of epiblast

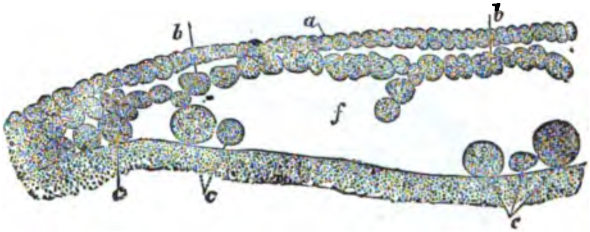

Fig. 138.—Section Through Part of Unincubated Fowl's Ovum (from *Haddon*, after *Klein*).—*a*, Epiblast; *b*, lower layer cells; *f*, archenteron; below this, yolk.

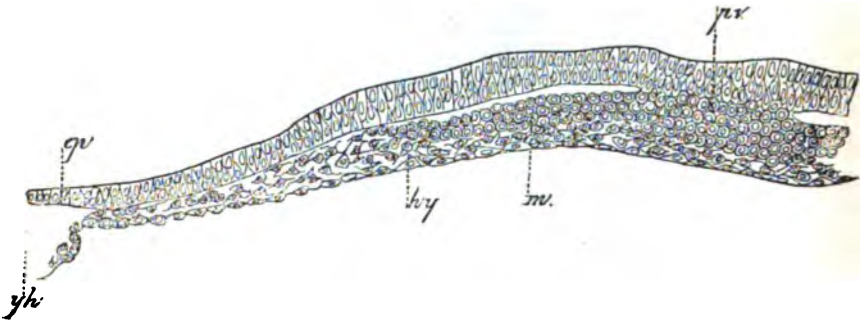

Fig. 139.—Transverse Section Through Front End of Primitive Streak in First Day Chick (see Fig. 140)—(From *Haddon*, after *Balfour*).—Columnar epiblast above, two cells thick. *Pv*, Region of primitive streak, where rounded mesoblast cells are originating from the epiblast; *hy*, hypoblast, above it, at the side, are stellate mesoblast cells of hypoblastic origin. N.B.—*Pv* is placed over the middle line.

(Fig. 139), which forms part of the **mesoblast.** It grows out laterally, and is reinforced by those lower layer cells which have not united to form hypoblast. In the *anterior* part of the blastoderm, *i.e.*, in front of the primitive streak, the lower layer cells form—(1) a thin layer of **hypoblast**, (2) two lateral sheets of **mesoblast**, (3) an axial rod of cells, the *notochord*, at first closely united with the hypoblast.

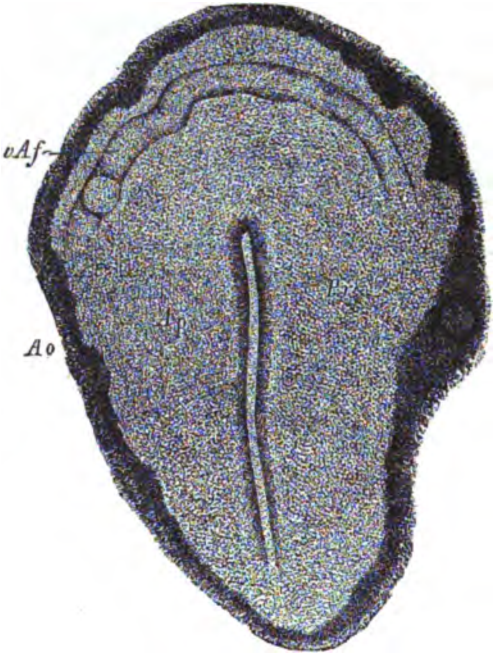

Fig. 140.—SURFACE VIEW OF FIRST DAY (20 HRS.) CHICK (from *Haddon*, after *Kölliker*).—*A.o*, Area opaca, bounding *A.p*, area pellucida; *Pr*, primitive streak; *Af*, head-fold.

The blastoderm thus comes to be three-layered, both in front and behind.

2. General Growth.—The blastoderm forms at first a circular curved plate resting upon the yolk. It gradually grows in all directions, and ultimately completely encloses the yolk. This enclosure is mainly effected by the *area opaca*. The body of the embryo is formed in the *area pellucida*. This elongates (Fig. 140), becoming somewhat pear-shaped, the broad (head) end being anterior. In front of the primitive streak a *medullary plate* is formed (*comp. p.* 273), upon which is a longitudinal *medullary groove*. This is bounded at the sides by the *medullary folds* (Fig. 141, *Mn*), which unite above to form the *neural tube*. The folds first unite in the region of the mid-brain. The *head* now projects from the surface of the yolk, and makes with it, as seen from the left side, an S-shaped *head-fold*. A similar *tail-fold* is formed later, and then *lateral folds*. The embryo, at first flattened out on the curved yolk-surface, thus gradually comes to assume the form of the chick, and the ever-diminishing yolk remains attached to its ventral surface (Fig. 145). In a chick at the end of the second day of incubation (Fig. 142), the *cerebral vesicles* (*Vh*, *Mh*, and *Hh*) are present, and the optic and auditory organs are commencing. The front part of the brain begins to bend round the end of the notochord. At the end of

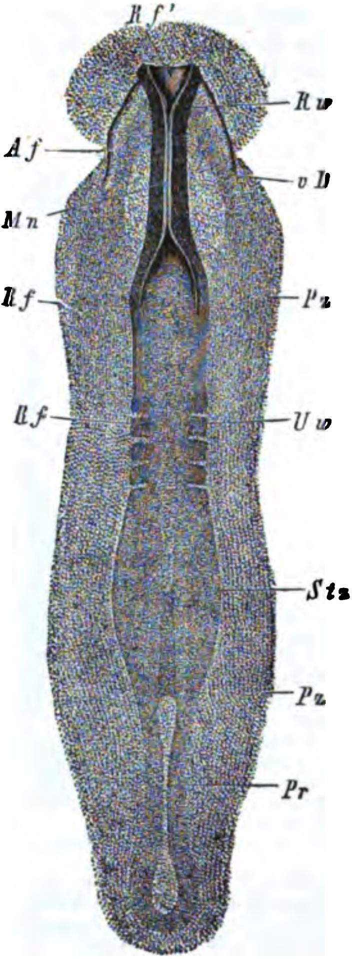

Fig. 141.—SURFACE VIEW OF CHICK, RATHER LATER THAN FIG. 140—Magnified 39 diameters (from *Haddon*, after *Kölliker*).—*Mn*, Medullary folds uniting in the head region; *Pr*, primitive streak; *vAf*, head-fold. Three mesoblastic somites are visible on either side of *Rf*.

the third day, the front part of the embryo is twisted round so as to lie with its left side on the yolk, and the *cranial flexure* round the notochord is well-marked. Five *visceral arches* and four *visceral clefts* have made their appearance (Fig. 143, A and B, v.c′ and v.c″), one less than in the Frog. The most posterior of these are very small. The prominent *heart* is situated just under the throat, close to the ventral ends of the visceral arches. The eye and ear are much more advanced, and the nasal sacs are

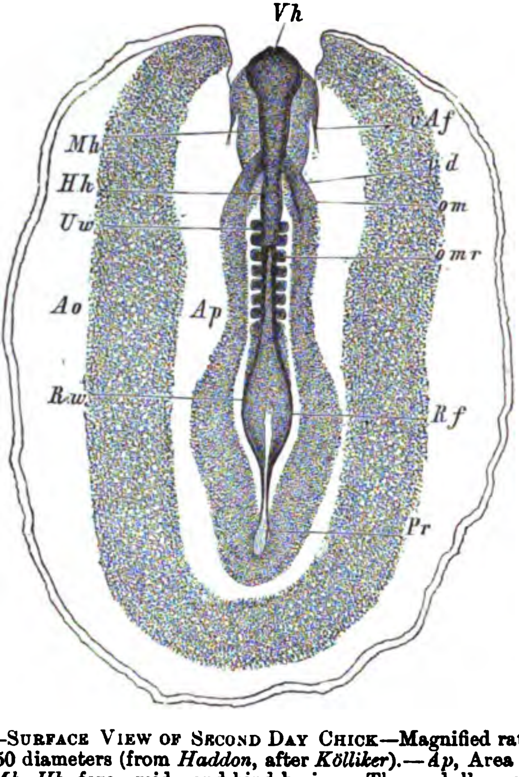

Fig. 142.—SURFACE VIEW OF SECOND DAY CHICK—Magnified rather more than 50 diameters (from *Haddon*, after *Kölliker*).—*Ap*, Area pellucida; *Vh*, *Mh*, *Hh*, fore-, mid-, and hind-brains. The medullary groove has closed as far back as *omr*. *Pr*, Primitive streak. Eight mesoblastic somites are shown.

commencing as pits. On the fourth day the limbs appear as buds. The chick is hatched on about the twentieth day of incubation, breaking the shell with its beak.

3. **Fate of the Germinal Layers.**—These give rise to the same organs as in the Frog (*p.* 274), but there are differences which will be here briefly noted. (1) The **epiblast** does not become divided into superficial and nervous layers till comparatively late, and the membranous labyrinth commences as a pit open externally. (2) The **hypoblast** presents no important differences, but the *notochord* (Figs. 143, *nch*, and 144, *ch*), entirely disappears in the adult. (3) The **mesoblast** becomes divided (*compare p.* 275) into *vertebral* and *lateral plates* in the region of the trunk, the former being again divided into *mesoblastic somites* (Figs. 141 and 142). The body-cavity (Fig. 144) is as before the split between

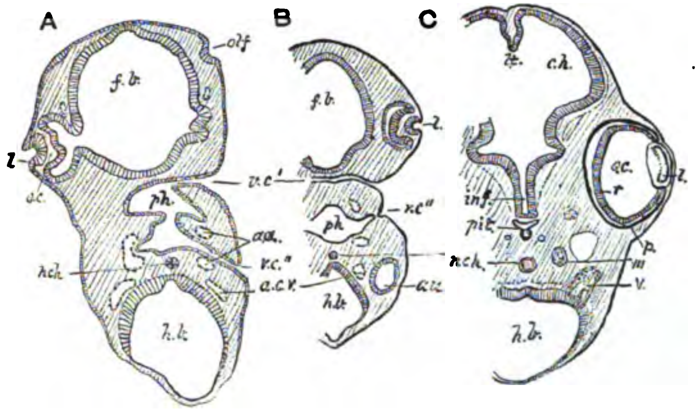

Fig. 143.—Development of the Eye (from *Haddon*, A after *Marshall*).—A and B sections through head. Third day chick. In A the optic vesicle (*o.c*) from the fore-brain (*f.b*) is becoming cup-like, *l* is the developing lens. In B the cup and lens are more distinct. Stalk of the former not cut through. C. Later stage—Inner wall of optic cup (*o.c*) forming most of retina, *r*—outer wall, *p*, forming pigment layer of ditto; *l*, lens (quite separated off). These sections incidentally illustrate other points. In all, owing to the cranial flexure, both fore- and hind-brains have been cut through (*f.b*, *h.b*). In C, *c.h*, *l.t*, and *inf*, indicate cerebral hemispheres, lamina terminalis, and infundibulum. Near the last is the pituitary body, *pit*. In A and B the pharynx (*ph*) is cut through, and the first two visceral clefts (*v.c'* and *v.c''*) are shown. *a.a*, aortic arches; *nch*, notochord.

the somatic and splanchnic layers of the lateral plates, the former uniting with the epiblast to form the *somatopleure* (*so*), the latter with the *hypoblast* to form the *splanchnopleure* (*sp*). When the embryo is spread out flat on the yolk, the somatopleure and splanchnopleure belonging to opposite sides diverge widely, but, as the embryo is folded off, they gradually approach, unite, and form a continuous boundary to the body and alimentary canal respectively. The latter meets in front and behind with in-pushings of epiblast that form the mouth-cavity and posterior part of the cloaca (stomodæum and proctodæum).

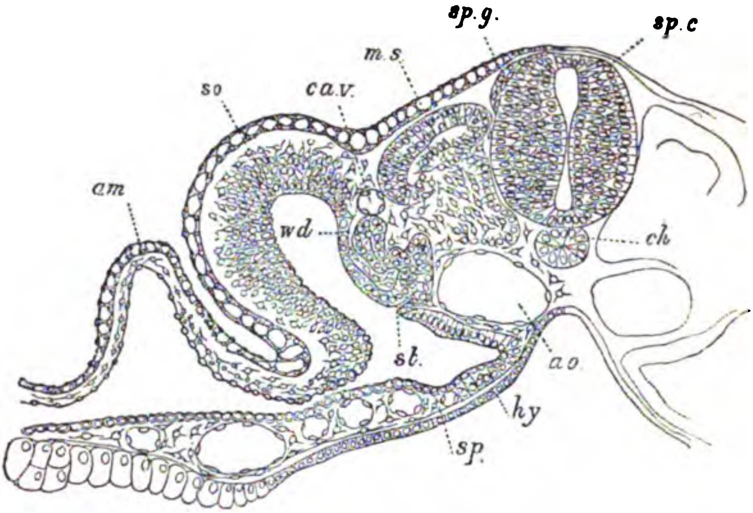

Fig. 144.—Transverse Section through Embryo Duck at Third Day (from *Haddon*, after *Balfour*).—The external layer is epiblast; *hy*, hypoblast; mesoblast, a thick layer between the two: *am*, lateral amniotic fold; *so*, somatopleure; *sp*, splanchnopleure (the reference letters *wd* and *sb* are placed in body-cavity); *sp.c*, spinal cord, at the side of which is section through mesoblastic somite; *ch*, notochord (the reference letters *ao*, *hy*, *sp* are placed in the alimentary canal, the walls of which, at this stage, are widely divergent).

The first three visceral arches are supported by skeletal structures that become in the adult:—

I. *Mandibular*	— Quadrates and Meckel's Cartilages, Palatines and Pterygoids.		
II. *Hyoid*,	fuse ventrally to form,	basi-hyal,	anterior cornua.
III. *Branchial* 1,		basi-branchial,	posterior cornua.

The last two visceral arches, corresponding to branchials 2 and 3 of the Frog, are small and have no skeleton.

The *circulatory organs* are not complicated by the presence of gills. The *heart* is at first a simple tube, which first becomes twisted and then chambered. As in the Frog it gives off *aortic arches*, which run up the visceral arches (Fig. 143, *a.a*), and unite above to form the dorsal aorta.

Arches 1 and 2 are very transient.

3rd Arches become	. . .	internal carotids.
4th Arches ,,	*right*, . .	aorta.
	left, . .	left subclavian.
5th Arches ,,	. . .	pulmonary arteries.

The *veins* of the embryo at first (3rd day) consist of paired *anterior cardinals* (= adult jugulars) and *posterior cardinals*, which bring back blood from the anterior and posterior parts respectively. The anterior and posterior cardinal of either side unite to form a *Cuvierian duct* (= adult precaval), which enters the heart. The posterior cardinals are supplanted later on by the development of a postcaval.

The course of the embryonic circulation will be discussed below.

Excretory Organs.—A very rudimentary **pronephros** is first developed, the duct of which originates the same structures (*p.* 276) as in the Frog. The **mesonephros** (Wolffian body) does not, however, become the excretory organ of the adult, but is succeeded by a **metanephros**, or true **kidney**. The only conspicuous remnant of the Wolffian body that persists after embryonic life is its duct, the Wolffian duct, which becomes the vas deferens of the male.

4. Embryonic Appendages (Fig. 145).—These are important structures connected with, but not forming part of, the embryo. To understand them, it is not only necessary to remember that the blastoderm gradually grows round the yolk, but also that the mesoblast splits here, as elsewhere, and both somatopleure and splanchnopleure are present. As the embryo (*e*) is folded off

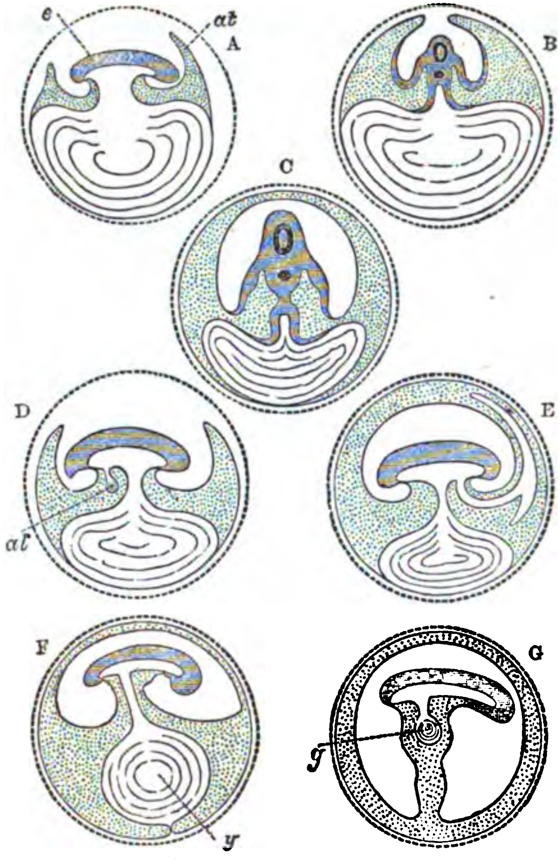

Fig. 145.—Diagram to Illustrate the Development of the Amnion and Allantois (from *Haddon*, after *Foster* and *Balfour*).—In A the embryo (*e*) is being constricted off from the yolk-sac, and the folds of the amnion are seen to be rising up at either end of the embryo, the anterior fold (*at*) being the larger; in B (a transverse section) the amniotic folds nearly meet, and in C (also a transverse section) they have entirely coalesced. In D (a rather later stage than A), the allantois (*al*) is budding out from the alimentary canal; in E (side-view corresponding to C), the allantois is seen extending round the embryo. In F, the yolk-sac (*y*) is reduced in size, and in G it is being withdrawn into the embryo's body. Allantois omitted in F and G. These diagrams only roughly indicate the relation of parts. In all, the embryo is represented by horizontal shading, the body-cavity is dotted, and the yolk-sac has concentric lines. The dotted line represents the vitelline membrane.

from the yolk; this, with its covering of splanchnopleure comes to form a sort of (y) bag, the **yolk-sac**, attached to the ventral side of the embryo by a stalk continuous with the walls of the alimentary canal. The yolk is gradually used up during development, so that the yolk-sac becomes smaller, and at last passes into the body. The continuation of the *somatopleure* outside the boundary of the body rises into folds, which grow up, and, finally meeting above the body, fuse together. Their *inner* layers form the **amnion**, a membrane enveloping the embryo, while their outer layers (and the somatopleure prolongation in the yolk-sac region) unite with the vitelline membrane. As the somato- and splanchnopleures are prolonged outside the region of the embryo, the space there present between them must be a continuation of the body-cavity. A flattened sac, the **allantois** (al), grows from the posterior part of the alimentary canal into this space, and extends over the embryo.

The yolk-sac possesses at one time a system of capillaries, and functions as a respiratory organ. As the allantois develops it also becomes very vascular, first assists the yolk-sac in respiration, and then carries it on entirely.

The urinary bladder of the Frog is a rudimentary allantois.

Course of the Embryonic Circulation.—The dorsal aorta sends *vitelline* and *allantoic arteries* from its posterior part to the yolk-sac and allantois respectively. These structures return purified blood to the body by *vitelline* and *allantoic** *veins*. These unite and form, with a vein from the alimentary canal, a trunk called the *ductus venosus*, which traverses the liver (giving off twigs in its course), and enters the now-developed postcaval. This communicates with the right auricle, and its (mostly) purified blood is directed by the Eustachian valve through the *foramen ovale*,† an aperture existing at this time in the auricular septum, into the left auricle. Thence it passes into the left ventricle, and so to the dorsal aorta. The right auricle also receives impure blood by the Cuvierian ducts. This passes into the right ventricle, whence, by the pulmonary artery, it reaches the lungs and also, to some extent, the dorsal aorta, by a cross branch, the

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* = *Anterior abdominal vein* of Frog.

† Its position is marked by the *fossa ovalis* of the adult.

ductus arteriosus. The lungs, now functionless, return impure blood to the left auricle It will be seen that, in the embryo, the comparatively pure blood of the left ventricle is derived from the *right side* of the heart. As soon as *lung-respiration* commences, the foramen ovale closes, the system of the ductus venosus becomes the *hepatic portal system* (that vessel being abolished as a continuous trunk), and the ductus arteriosus aborts.

CHAPTER VIII.—MAMMALIA.

§ 11. LEPUS CUNICULUS (The Rabbit).

The wild Rabbit, which is here described, forms the parent-stock from which the different kinds of tame Rabbit have sprung, and which differ from it in no important points of structure.

MORPHOLOGY.

1. External Characters.—The body is bilaterally symmetrical, and is divided into the same regions as in the Pigeon—*i.e.*, *head*, *neck*, *trunk*, and *tail.* The neck is short, however, but the tail, though short, is distinct. The *fore-* and *hind-limbs* are adapted for quadrupedal progression. Almost all the external surface is covered by *hair*, but a bare *perineal space* is present on either side near the root of the tail.

The *head* is elongated and tapers in front into the snout. Here the *mouth* is found as a transverse slit bounded by soft mobile *upper* and *lower lips*, the former of which is cleft. The *external nares* are two oblique slits near the tip of the snout, which converge in front to the cleft of the upper lip. Long stiff hairs, the whiskers or *vibrissæ*, are present on the sides of the snout as well as in the neighbourhood of the eyes. These are large, and protected by *upper*, *lower*, and *third eyelids.* Each of the two first is fringed by a row of stiff *eyelashes*, while the last is a bare opaque white membrane, usually folded up in the anterior angle of the eye. It is supported by a plate of cartilage. The *auditory aperture* on either side is situated some distance behind the eye, and is guarded by a long backwardly and upwardly directed flap, the *pinna*, the base of which is supported by cartilage.

The pinna varies very much in size and position in tame rabbits, especially in lop-eared varieties.

The **trunk** is somewhat flattened from side to side. It is divided into a relatively small *thorax* in front, bounded by hard parts, and a large *abdomen* behind, with, for the most part, soft walls, laterally and ventrally. There are, in the *female*, five to six pairs of *teats* on the ventral surface, belonging to the *mammary glands*. The anterior *thoracic* pair are furthest apart. Upon each teat are the small openings of the corresponding gland.

Immediately beneath the tail the rounded *anus* is situated, and a little in front of this the *urogenital aperture*, varying in character according to sex. In front of this the hard *symphysis* of the pubes and ischia can be felt. The space between the anus and urogenital aperture is known as the *perineum*, and on either side of this there is a bare, pouch-like depression, the *perineal space*, upon which is a small papilla that bears the aperture of the *perineal gland* of that side.

The *fore-limb* is divided into *brachium*, *antebrachium*, and pentadactyle clawed (unguiculate) *manus*. The much longer *hind-limb* is divided into *femur*, *crus*, and elongated tetradactyle clawed *pes*.

Position of Body.—In the standing posture the *elbow* is directed backwards, the *knee* forwards, and the *ankle-joint* backwards. Both limbs are disposed in vertical planes, and the body is lifted well off the ground (*compare p.* 225).

2. Skin.—The skin is thick, and made up of *epidermis* and *dermis*, the hairs being developments of the former. The *mammary* and *perineal glands* belong to the skin, and they are imbedded in the underlying, *subcutaneous*, connective-tissue, which is everywhere abundantly present. Beneath and closely connected with this is a thin sheet of striated muscle, the *panniculus carnosus*, on the ventral side of the neck and trunk.

Histology (Fig. 146).—Each *hair* commences (in the embryo) as a thickening of the Malpighian layer of the epidermis that projects towards the dermis (B, C, D). This *hair-germ* gradually becomes converted into a *hair-follicle* (E and F), at the bottom of which is a *hair-papilla* (*P* and *P′*). A special investing sheath is formed by the dermis, which also penetrates into the hair-papilla and makes it vascular (*P′*). The *hair,* developed from the epidermis of the hair-papilla, exhibits an external firmer *cortex,* covered by a scaly *cuticle,* and a softer internal air-containing *medulla,* which, in coloured hairs, is pigmented. Small branched *sebaceous glands* (*Dr*), secreting an oily substance, open into the follicle near its mouth, and with it are also connected bands of unstriated muscle, by contraction of which the hair is erected.

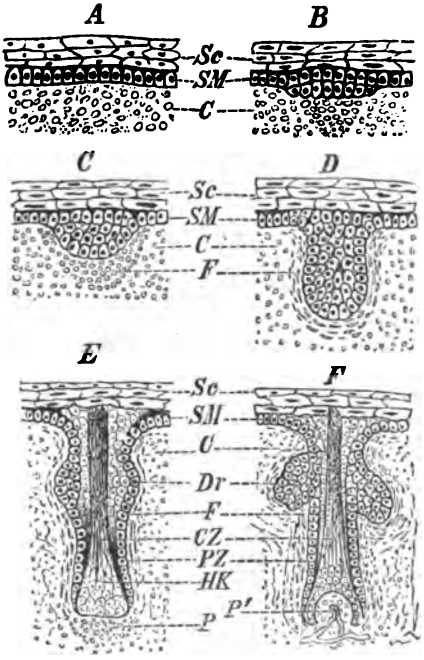

Fig. 146.—Six Stages in the Development of Hair (from *Haddon,* after *Wiedersheim*).—*Sc,* Horny layer; *SM,* Malpighian layer; *C,* dermis; *F,* hair-follicle; *Dr,* sebaceous glands; *CZ,* shaft of hair; *PZ,* hair sheath; *HK,* hair germ; *P′,* hair-papilla; *P,* commencement of ditto.

The hairs are continually being shed, and are replaced by new ones developed on papillæ that are connected with the old hair-follicles.

The *mammary* and *perineal glands* are made up of tubules, dilated at their ends, and lined by glandular epithelium continuous with the epidermis.

The *dermis* is rich in blood-vessels, lymphatics, and nerves, and many nerve-fibres end in elongated oval *touch-corpuscles.* One of these is closely connected with the base of each vibrissa.

3. Endoskeleton (Fig. 147).—This is made up of the usual histological elements.* The bones are much more compact than those of the Pigeon, and the shafts of the long bones contain marrow.

(1.) *Axial Endoskeleton*—(*a.*) **Skull** (A and A′).—As in the Pigeon, the mature skull is mostly composed of bones, but these are comparatively little fused together, many of the boundaries remaining apparent, even in old animals. They are united, in many cases, by finely jagged edges, which interlock. These unions are called *sutures.*

A small posterior *cranial* portion may be distinguished from a much larger *facial* portion. The boundary between the two is indicated by the large *orbits.*

The *brain-case,* which forms most of the cranial part, is perforated behind by the large *foramen magnum,* bounded by the *ex-occipital* (*ex-oc*) on either side, the *supra-occipital* (*s-oc*) above, and the *basi-occipital* below, all closely fused in the adult. There are two smooth oval *occipital condyles* (*c*), one on each side of the foramen magnum, mainly formed by the corresponding ex-occipitals, but partly by the basi-occipital. This last is a small, flat bone. Each ex-occipital is produced downwards into a long *par-occipital process* (*par*), closely applied to the hinder part of the tympanic bulla (*see below*). The large, irregular supra-occipital is raised into a prominent, shield-shaped elevation. The roof of the brain-case is completed by inter-parietal, parietal, and frontal bones. The *inter-parietal* (*i-p*) is a small, unpaired bone, placed transversely, and partly shutting out the *parietals* (*pa*) from union with the supra-occipital. These are large, flattish bones, united together by a longitudinal *sagittal suture*, and with the supra-occipital and inter-parietal by the transverse *lamboidal suture*. A slender process runs downwards from the outer side of each. The *frontals* (*fr*), which cover the front of the rapidly-narrowing brain-case, are united with each other by the median *frontal suture*, and with the parietals by the transverse *coronal suture*. Each is very irregular in shape, and possesses parts situated in very different planes. That part roofing the brain-case is broadest behind, and tapers anteriorly, to form with its fellow a sharp point. From the side of this part a plate-like *orbital process* (*fr.*) turns sharply downwards and inwards to form the upper part of the inner orbital wall. Where it turns down, a large overhanging *supra-orbital process* sticks out, which partly roofs the orbit. A process from the frontal runs into the nasal region. The floor of the brain-case rapidly steepens in front of the basi-occipital, and is formed in the middle line by the basi- and pre-sphenoids, on either side by the ali- and orbito-sphenoids. The *basi-sphenoid* is a small bone with a broad posterior end separated from the basi-occipital by a thin plate of cartilage, and a narrow anterior end united by cartilage to the pre-sphenoid (× *placed at junction*). Upon its upper surface is a pit, the *sella turcica* (for the pituitary body), bounded behind by the *posterior clinoid processes.* Firmly fused to either side of the basi-sphenoid is a thin wing-like expansion, the *ali-sphenoid* (*a-s*). From the under side of this a transverse lamella, the *external pterygoid process*, passes vertically downwards. The *pre-sphenoid* is a vertical plate, the upper surface of which is produced backwards into the *anterior clinoid processes* which bound the sella turcica in front. After limiting the *optic foramen* below, the pre-sphenoid ends in two diverging lamellæ which articulate above with the orbital processes of the frontal, and help to form the inner wall of the orbit (*pr-s*). A wing-like *orbito-sphenoid* (*or-s*) is firmly fused with the pre-sphenoid on either side. It forms the hinder and upper boundaries of the optic foramen, unites with the orbital process of the frontal above, and the ali-sphenoid behind. The narrow front end of the brain-case is filled in by the *cribriform plate* (*below ol in Fig.* 148), a lamella perforated by numerous holes which forms the party-wall between the cranial and nasal cavities. It is the hinder part of the *mesethmoid* bone (*see below*). The side-wall of the skull is largely formed in its posterior region by the *squamosal* (*sq*), which fills up the gap between parietal and ali-sphenoid, unites in front with the frontal and orbito-sphenoid, and behind overlaps the descending process of the parietal. A delicate backward process from the squamosal helps to keep the large, irregular *periotic* (which completes the side-wall and floor between ali-sphenoid and ex-occipital) in place, and a large *zygomatic process* (*z.s*) runs outwards and forwards from it just behind the orbit.

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* 1. *Cartilage bones:—Ex-, supra-, and basi-occipitals; basi-, pre-,* and *orbito-sphenoids; mesethmoid, periotic, malleus, incus, os orbiculare, stapes, turbinals, palatine, pterygoid, hyoids, Vertebræ, Ribs, Sternum, Appendicular endoskeleton* (except clavicle). 2. Membrane bones:—Interparietal, parietal, frontal, squamosal, tympanic, vomer, lachrymal, nasal, premaxilla, maxilla, jugal, mandible. Clavicle.

The *auditory capsule* is formed by the *periotic* (*per* and *A'*) bone mentioned above, and this results from the early fusion of *pro-*, *epi-*, and *opisthotic* elements. The outer and hinder *mastoid* portion of this bone is porous, and a tapering *mastoid process* (*m.pr*) runs down from it in front of the par-occipital process. The inner side of the mastoid part presents a deep rounded pit, the *floccular fossa*, for the flocculus of the cerebellum. The *petrous portion* which forms the rest of the periotic is very dense, and contains the membranous labyrinth. Upon its outer surface there is a smooth projection, the *promontory* (*A'*, *pr*), above which is the elliptical *fenestra ovalis* (*f.ov*), and behind it the more irregular *fenestra rotunda* (*f.ro*). Closely applied to this outer surface is the *tympanic* (*ty*), a bone with a dilated lower part termed the *bulla*, and a short tubular part directed upwards and backwards. The inner side of both is incomplete, for which the periotic makes up, forming the inner wall of the *tympanic cavity*, which is contained in the bulla. The tubular part supports the external auditory meatus, and, at its junction with the bulla, the *tympanic membrane* is stretched over a flattened rim which projects into the latter. Extending across the tympanic cavity are four minute bones (*A''*)—(1) The *malleus* (*m*), which possesses two slender processes (one, the *manubrium*, attached to the tympanic membrane), which are given off from a rounded head. This articulates by a saddle-shaped surface with the head of (2) the *incus* (*i*), which gives off a small process backwards and a slender one downwards. The latter is bent up at its tip, and connected by a minute disc (3), the *os orbiculare*, with (4) the stirrup-shaped *stapes* (*st*), the oval base of which fits into the fenestra ovalis. The Eustachian tube enters the tympanic cavity below and in front by a very short canal, formed by the apposition of a groove in the tympanic to the surface of the periotic.

The par-occipital and mastoid processes overlap the tympanic behind, and hold it in place.

The cavity of the brain-case closely corresponds to the shape of the brain, and is divided into a small *olfactory fossa* in front, ill-marked off from the large *cerebral fossa,* which extends back to the anterior limit of the periotics and supra-occipital, where a sharp ridge separates it from the *cerebellar fossa.*

NERVE-EXITS.

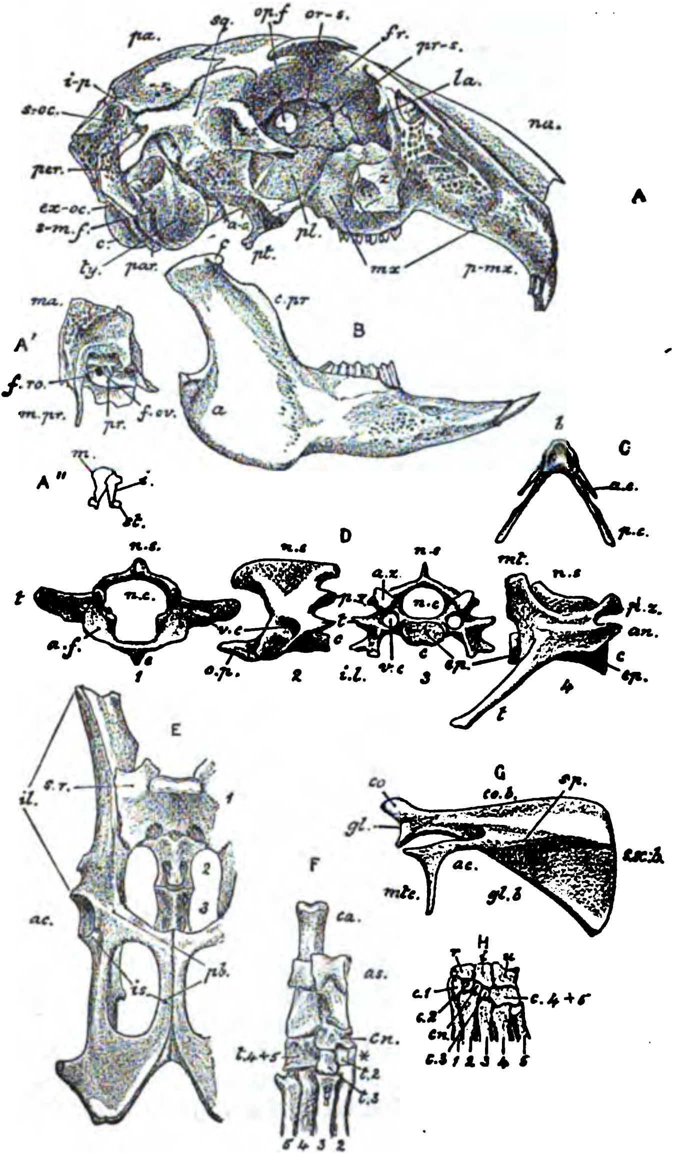
I. *Olfactory.*	Numerous olfactory foramina.	Cribriform plate.
II. *Optic.*	Optic foramen (*op.f*).	A large unpaired aperture, bounded by pre- and orbito-sphenoids, which places hinder end of orbits in communication with each other and the cranial cavity.
III. *Oculomotor.*	Sphenoidal fissure.	Between basi- and ali-sphenoid on either side.
IV. *Pathetic.*		
VI. *Abducent.*		
V. *Trigeminal—*		
a. Orbito-nasal.		
b. Maxillary.		
c. Mandibular.	Foramen lacerum medium.	Between ali-sphenoid and periotic.
VII. *Facial—* Enters periotic by	Aqueductus Fallopii.	Just below the floccular fossa.
Leaves skull by	Stylomastoid foramen (*s-m.f*).	Between mastoid process and tympanic.
VIII. *Auditory—* Enters periotic by	Meatus auditorius internus.	Just behind aqueductus Fallopii, and sunk in a depression with it.
IX. *Glossopharyngeal.*	Foramen lacerum posterius.	Between periotic and ex-occipital.
X. *Vagus.*		
XI. *Spinal Accessory.*		
XII. *Hypoglossal.*	Condylar foramina (2).	In ex-occipital, near the condyle.

The *facial* part of the skull consists of the nasal capsules and upper jaw with associated parts. The *nasal capsules* are separated from the cranial cavity by the cribriform plate, from which a vertical partition, bony behind (*lamina perpendicularis*), cartilaginous in front (*septum nasi*), extends forwards and separates the two capsules. This partition, together with the cribriform plate, constitutes the *mesethmoid*, and its lower edge rests in a deep furrow on the upper surface of the elongated *vomer*. The posterior wall of each capsule is partly formed by the small *lachrymal* (*la*), which also makes up part of the anterior orbital wall. Its outer side is deeply notched to transmit the *lachrymal duct*. The capsule is partly roofed in behind by the frontal, but mainly by an elongated flat *nasal* (*na*), which, with the premaxilla, largely bounds the external naris. The capsular side-wall and floor are principally formed by the premaxilla and maxilla. The nasal cavity (Fig. 148) contains the *ethmo-turbinal* (*e-t*) behind and above, a bone made up of thin lamellæ disposed in a complex manner, which is fused with the cribriform plate, and a similarly constructed but more delicate *maxillo-turbinal* (*m-t*) in front. From the nasal bone a delicate curved fold, the *naso-turbinal*, projects into the cavity.

The margin of the *upper jaw* is formed in front by the *premaxillæ* (*p-mx*) which contain sockets for the upper incisor teeth. Each sends an elongated *nasal process* upwards and backwards along the outer edge of the nasal, a delicate *palatine process* backwards along the roof of the mouth, and a stout *maxillary* process backwards and outwards to unite with the *maxilla* (*mx*). This is a large, extremely irregular bone that forms the jaw-margin with the premaxilla, a little way behind which bone it dilates to contain the sockets of the grinding teeth, and projects into the front part of the orbit. The maxilla also forms a large part of the side-wall of the nasal capsule, and in this region is very loose in texture. From its external side, above the grinding teeth, a stout *zygomatic process* (*z*) projects, which is connected by the laterally flattened *jugal* with the zygomatic process of the *squamosal* to form the *zygomatic arch*, a bony bar forming the lower boundary of the orbit. A small, horizontal *palatine process* runs from the inner side of the maxilla, and unites with its fellow in the middle line to form the front part of the *bony palate* (Fig. 148, *b.p*) a transverse bridge of bone between the first four grinding teeth of opposite sides. The inner surface of the maxilla behind this is covered by the *palatine* (*pl*), a thin vertical plate uniting above with the orbital process of the pre-sphenoid. The bony palate is completed behind by the horizontal *palatine process* of this bone which unites with its fellow. The *posterior nasal chamber* (Fig. 148, *p.n.c*), is bounded laterally by the palatines, which are united behind with the downward processes of the ali-sphenoids, and with the *pterygoids* (*pt*). Each pterygoid is a small plate behind, and in the same plane as the palatine. It is produced below into a curved *hamular process*, and connected above with the junction between basi- and ali-sphenoids.

Mandibular Arch.—The *incus* and *malleus* represent the upper part of this arch, from which the *pterygoid* and *palatine* are a forward outgrowth. In the adult a *Eustachian cartilage* behind the former bone, placed in the wall of the Eustachian tube, indicates the original continuity. The remainder is a single bone forming one half or *ramus* of the *mandible*, uniting in front with its fellow in the mandibular symphysis, and articulating behind by a longi-

Fig. 147.—ENDOSKELETON OF RABBIT.—A, Skull (*jugal* bone removed); *s-oc*, supra-occipital; *ex-oc*, ex-occipital; *c*, condyle; *par*, par-occipital process; *s-m.f*, stylo-mastoid foramen; *ty*, tympanic; *per*, periotic; *i-p*, inter-parietal; *pa*, parietal; *a-s*, ali-sphenoid; *sq*, squamosal; *z.s*, zygomatic process of squamosal; *pt*, pterygoid, *fr*, frontal; *or-s*, orbito-sphenoid; *pr-s*, pre-sphenoid; *pl*, palatine; *mx*, maxilla; *z*, zygomatic process of ditto (with cut end); *p-mx*, pre-maxilla; *la*, lachrymal; *na*, nasal, *op-f*, optic foramen; × placed at junction of basi- and pre-sphenoid. A′, Outside of periotic, after removal of tympanic; *ma*, mastoid portion; *m.pr*, mastoid process; *pr*, promontory; *f.ov*, fenestra ovalis; *f.ro*, fenestra rotunda. A″, Auditory ossicles from inside; *m*, malleus; *i*, incus; *st*, stapes. B, *Mandible*; *c*, condyle; *a*, angle; *c.pr*, coronoid process. C, Hyoid apparatus; *b*, body; *a.c*, anterior cornu; *p.c*, posterior cornu. D, Various vertebræ; 1, atlas (front view); 2, axis; 3, typical cervical (front view); 4, typical lumbar; *c*, centrum; *n.s*, neural spine; *t*, transverse process; *a.f* (in atlas), articular facet for condyle; *a.z*, prezygapophysis; *p.z*, postzygapophysis; *n.c*, neural canal; *v.c*, vertebrarterial canal; *o.p*, odontoid peg; *i.l*, cervical rib; *ep*, epiphysis; *mt*, metapophysis; *an*, anapophysis. E, *Hip-Girdles and Sacrum*. 1, 2, 3, Sacral vertebræ; *s.r*, sacral rib; *il*, ilium; *pb*, pubis; *is*, ischium (reference letter placed in obturator foramen); *ac*, acetabulum. F, Right tarsus; *as*, astragalus; *ca*, calcaneum; *cn*, centrale; *t*, 1-5, *tarsalia*; 2–5, metatarsals; *, placed by process of met. 2, representing hallux. G, *Left Scapula*—*s-sc.b*, *co.b*, *gl.b*, supra-scapular, coracoid, and glenoid borders; *sp*, spine; *ac*, acromion; *mtc*, metacromion; *co*, coracoid process; *gl*, glenoid cavity. H, *Left Carpus*—*r*, Radiale; *i*, intermedium; *u*, ulnare; *cn*, centrale; *c*, 1–5, carpalia; 1-5, metacarpals.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tudinally elongated *condyle* (*c*) with the *glenoid fossa,* a smooth hollow on the under side of the zygomatic process (*z.s*) of the squamosal. It is laterally flattened and composed of an anterior horizontal part bearing sockets for the lower teeth, and a posterior ascending part ending in the condyle above—in front of which is the *coronoid process* (*c.pr*)—and uniting with the horizontal portion in the rounded *angle* (*a*).

Hyoid Arch (*c*).—The proximal end of this is formed by the *stapes.* The "hyoid apparatus" consists of a small *basi-hyal* (*b*) imbedded in the root of the tongue, and with which are connected short *anterior* and long *posterior cornua* (*a.c* and *p.c*) The anterior cornua represent the *hyoid arches* of the embryo, and are connected by ligaments with the skull, close to the mastoid processes. In this region a small part of the hyoid arch (*tympanohyal*) is fused to the skull. The posterior cornua represent the *first branchial arches.*

(*b.*) **Vertebral Column and Ribs.**—The vertebral column is divisible into *cervical, thoracic, lumbar, sacral,* and *caudal* regions. Except in the sacral region the vertebræ remain distinct from one another, and the more or less flat ends of the centra are connected together by cartilaginous discs, intervertebræ, which come between them. The front and back of each centrum ossify independently as thin bony plates, *epiphyses* (D, *ep*), which fuse later on with the middle part. The spinal nerves exit as in the other types by *intervertebral foramina* between adjoining arches, and *neural spines* and *zygapophyses* of the usual kind are present.

The *cervical vertebræ* (D, 3) are seven in number. Their centra (*c*) are short, and their neural spines (*n.s*) small. The cervical ribs are not free but fused, as in most of the Pigeon's cervical vertebræ (*comp. p.* 286). The apparent transverse processes are thus perforated at their bases to form the *vertebrarterial canal* (*v.c*), and are divided into two parts, the upper of which is true *transverse process* (*t*), the lower or *inferior lamina* (*i.l*), the projecting part of the fused rib.

The *atlas* (D,1) or first cervical vertebra is ring-like, possesses large transverse processes (but no inferior laminæ), and a thin narrow centrum. It presents in front two large oval articular surfaces (*a.f*) for the occipital condyles, and behind two smaller concavities for the axis, but there are no true zygapophyses.

The *axis* or second cervical vertebra (D, 2) has an *odontoid peg* (*o.p*), (which ossifies separately), projecting forwards above the centrum of the atlas. A convex articular surface is present on the under side of the peg, which plays upon a corresponding surface on the upper side of the atlas-centrum, and there are also two large convexities on either side of its base which fit into the two shallow cups on the hind end of the atlas. The neural spine of the axis is a prominent ridge which bifurcates behind. It possesses no præ-zygapophyses.

The *last* (seventh) cervical vertebra has a half-facet on the side of the centrum, at its hinder end.

The *thoracic* vertebræ are 12 (or 13) in number, and are characterized by the possession of free thoracic ribs. They increase in size from before backwards, their centra, which are thick from above downwards, elongating. The neural spines of the first 9 are slender and backwardly directed, that of the tenth is vertical, and those of the remainder slope forwards like the lumbar spines. From the ninth backwards *metapophyses* appear, stout processes directed upwards and forwards in the region of the præ-zygapophyses. The transverse processes of the first nine possess *tubercular facets* on the under sides of their tips, and *capitular half-facets* on the sides of their centra, one in front, the other behind. The last 3 (or 4) have entire *capitular facets* on the sides of their centra, situated near the front.

The *ribs* are curved flattened rods, increasing in length up to the sixth, and then shortening. Each consists of a bony *vertebral portion*, the proximal end of which, in the first 9, is forked, possessing tubercle and capitulum (*comp. p.* 286), and of a much shorter *sternal part* of more or less ossified cartilage. The tubercles of the ribs articulate with the tubercular facets, and the capitulum of each of the first 9 articulates with a capitular facet, formed in part by the anterior half-facet of its own vertebra, in part by the posterior half-facet of the preceding vertebra (the seventh cervical in the case of the first rib). The last 3 (or 4) ribs possess no tubercles, and their capitula articulate with the corresponding facets on their own vertebræ. The sternal parts of the first 7 ribs unite distally with the sternum, those of the remaining ones do not. This is the distinction between "true" and "false" ribs.

The *lumbar vertebræ* (D, 4) are 7 (or 6) in number. They are large, with elongated centra, laterally flattened neural spines, directed forwards, strong elongated transverse processes running downwards and forwards, and large *metapophyses* (*mt*). They also possess *anapophyses* (*an*), small backwardly directed processes given off below the post-zygapophyses. The first two also have *hypapophyses*, unpaired processes running downwards from the under side of the centra.

The *sacral vertebræ* (E) are 4 in number, closely fused together. The two first (1 and 2) possess fused *sacral ribs*, which form lateral wing-like expansions (*s.r*), articulating with the inner sides of the ilia.

The *caudal vertebræ*, about 15 in number, gradually get smaller towards the end of the tail, losing first their processes, and then their neural arches.

(*c.*) **Sternum.**—This is a narrow rod, made up of six laterally compressed segments or *sternebræ*, and placed in the mid-ventral line of the thorax. The first segment, or *manubrium*, is much larger than the others, and possesses a prominent ventral ridge. It is composed of two segments completely fused together, and this is indicated in the adult by the attachment of the first sternal ribs to the middle of its length. The remaining six pairs of sternal ribs are connected with the junctions of the sternebræ, one pair each to the first four, and two pairs to the last. The hindmost sternebra is elongated, slender, and terminated by a rounded plate of cartilage, with which it forms the *xiphisternum*.

(2.) *Appendicular Endoskeleton.*—The long bones are terminated as usual by epiphyses.

(*a.*) **Fore-Limb.**—The *shoulder-girdle* is mainly composed of the triangular *scapula* (*G*), placed external to the anterior ribs, where it is held in place by muscles and ligaments. Its enlarged apex presents a shallow *glenoid cavity* (*gl*) for the head of the humerus. The base, anterior, and posterior sides of the triangle are termed *supra-scapular*, *coracoid*, and *glenoid borders* respectively (*s-sc.b*, *co.b*, and *gl.b*). With the first a strip of cartilage, the *supra-scapula*, is connected. A conspicuous ridge, the *spine* (*sp*), runs along the outer surface of the scapula, and is produced below into a freely projecting process, the *acromion* (*ac*), from which a more slender *metacromion* (*mtc*) is given off behind. The coracoid border is continued below into a hook-like *coracoid process* (*co*). This is originally distinct, and represents a *coracoid bone*. A ligament runs from the tip of the manubrium to the acromion, in the centre of which is a slender curved *clavicle*. To the sternal end of this a minute nodule of cartilage is attached which represents a *pre-coracoid* (*comp. p.* 234).

Free Limb.—The *humerus* presents a proximal *head*, on its upper (dorsal) surface, for articulation with the glenoid cavity, and a distal pulley-like *trochlea*, which assists to form the elbow-joint. On the outer (preaxial) side of the head is a large projection, the *greater tuberosity*, and on its inner (postaxial) side a smaller projection, the *lesser tuberosity*. The radius and ulna, which support the antebrachium, are immovably articulated, but not fused together in the position of *pronation*.

Where, as in Man, the radius and ulna are movable, they may assume two main positions:—(*a.*) *Supination*, when they are parallel, the palm of the hand is upwards, and the thumb outside (like the radius). (*b.*) *Pronation*, when the radius crosses over the ulna towards the inside, the palm of the hand is downwards, and the thumb inside (like the distal end of the radius).

The preaxial *radius* possesses a proximal head for articulation with the trochlea, and two distal concavities for the carpal bones. The postaxial *ulna* has a proximal *siginoid cavity* for articulation with the trochlea, and a convex distal end. Proximally the ulna is produced into the *olecranon*, a process which, in the extended limb, fits into the *olecranon fossa*, a pit situated above the trochlea.

The *carpus* (F) consists of a proximal and a distal row of small bones, and a diminutive *centrale* (*cn*). The *proximal* row is made up of four bones, which are (beginning on the inner (preaxial) side)—(*r*) *radiale* (scaphoid), and (*i*) *intermedium* (lunar), articulating with the concavities on the radius, (*u*) *ulnare* (cuneiform), and *pisiform* (not shown), articulating with the convexity on the ulna. The *distal* row is made up of four carpalia (*c*, 1–5), which are, beginning as before, *carpale* 1 (trapezium), *carpale* 2 (trapezoid), *carpale* 3 (magnum), *carpale* 4 + *carpale* 5 (unciform). Five *digits* are present supported by five *metacarpals* (1–5) articulating with the corresponding carpalia, and completed by *phalanges*, of which the short *pollex* (1st digit) possesses 2, the others 3 each. The terminal phalanges are conical, and grooved to support the claws.

(*b.*) **Hind-Limb.**—The *hip-girdle* (E) is formed by an *innominate bone* on either side, made up of four fused bones, *ilium*, *ischium*, *pubis*, and *cotyloid*. Upon the outer side of each innominate is a deep cup, the *acetabulum* (*ac*), the floor of which is complete, and in the young Rabbit, marked by the three-rayed junction of the ilium, ischium, and cotyloid.

The last is a very small bone helping to form the ventral side of the acetabulum, from which it shuts out the pubis.

The *ilium* (*il*) is placed above and in front. It is laterally flattened, and the sacrum articulates with its inner surface. The *ischium* is placed above and behind. It is separated from the pubis by the oval *obturator foramen* (*is* placed in it), and presents posteriorly a rough and thickened tuberosity. A plate-like expansion runs from its hinder part towards the mid-ventral line, and unites there with its fellow to form the posterior portion of the *ischio-pubic symphysis*.

The small *pubis* (*pb*) runs from the cotyloid bone towards the mid-ventral line, and unites with its fellow to form the anterior part of the ischio-pubic symphysis.

Free Limb.—The elongated *femur* presents a proximal *head* upon its inner (preaxial) side, which articulates with the acetabulum, and two distal *condyles* which articulate with the tibia to form the knee-joint. The actual proximal end of the femur is a large projection known as the *great trochanter*. There is a *lesser trochanter* below the head, and opposite this on the outer (postaxial) side a *third trochanter*.

A large *patella* is present on the front of the knee-joint, at the back of which are two other sesamoid bones, the *fabellæ*.

The crus is supported by the large preaxial *tibia*, which possesses two proximal concavities for the femur, and two distal surfaces for the tarsus, the postaxial of which projects beyond the other. With the tibia a small, postaxial, rod-like *fibula*, is completely fused distally.

The ankle-joint in the Rabbit is between the distal ends of the above bones and the tarsus.

The *tarsus* (F) is made up of proximal and distal rows partly separated by a large (*cn*) *centrale* (navicular).

The *proximal* row contains two bones, the preaxial (*as*) *tibialo-intermedium* (astragalus), and postaxial (*ca*) *fibulare* (calcaneum) produced into a large projecting *heel*. The *distal* row is composed of three bones, which are, beginning preaxially, (*t* 2) *tarsale* 2 (mesocuneiform), (*t* 3) *tarsale* 3 (ectocuneiform), and (*t* 4 + 5) *tarsale* 4 + *tarsale* 5 (cuboid).

There are four *digits*, the first or hallux being absent. Each possesses a *metatarsal* (2–5), the first of which is produced proximally into a process (*), originally separate, which may represent the missing hallux. Each digit is completed by three *phalanges*, similar to these of the manus.

Small nodular *sesamoid bones* are developed in the tendons, opposite the joints on the under (ventral) side of manus and pes.

Histology.—The *cartilage* and *bone* making up the endoskeleton are similar in minute structure to those of the Pigeon, but the *Haversian canals* are larger.

4. **Digestive Organs** (Fig. 148).—These are contained, for the most part, in the abdominal cavity, which is separated from the thoracic cavity by a muscular partition, the *diaphragm* (*d*), and lined by the thin *peritoneum*, which forms suspensory mesenteric folds for the viscera.

The small *mouth* (*see Fig.* 148), guarded by flexible *lips*, leads into a large *mouth-cavity*, the roof of which is elongated, and presents a central part, the *palate*, bounded by the margin of the upper jaw. Just behind the front teeth there is a small oval elevation, into a groove on either side of which a *naso-palatine canal*, from the nasal cavity, opens. The anterior half of the palate, marked by firm transverse ridges, and the soft flexible posterior half, are called respectively *hard* and *soft palates*. The latter ends (*a little behind* *) in a free notched edge, on either side of which is a small thickening, the *tonsil* (*just above* *), indented by a pit. The *floor* of the mouth, bounded by the margins of the mandible, has the long muscular *tongue* (*t*) attached to the greater part of its extent. This exhibits in front a free tip, in the neighbourhood of which are numerous small *papillæ* that also extend back some distance on the upper surface. There is a hard elongated area above and behind, and, on either side of the posterior end of this, a *circumvallate papilla*, consisting of a small projection encircled by a groove (*a little way above p.f*). An oval elevation, the *papilla foliata* (*p.f*), across which numerous oblique ridges run, is present on each side of the tongue. The hair covering the body is continued into the sides of the mouth-cavity for a short distance.

The *teeth* (Fig. 147), definite in number, are imbedded in sockets, or *alveoli*, and are of three kinds. There are two sets of teeth, the first, *milk teeth*, very transitory, and succeeded by *permanent teeth*, which continue to grow throughout life as they

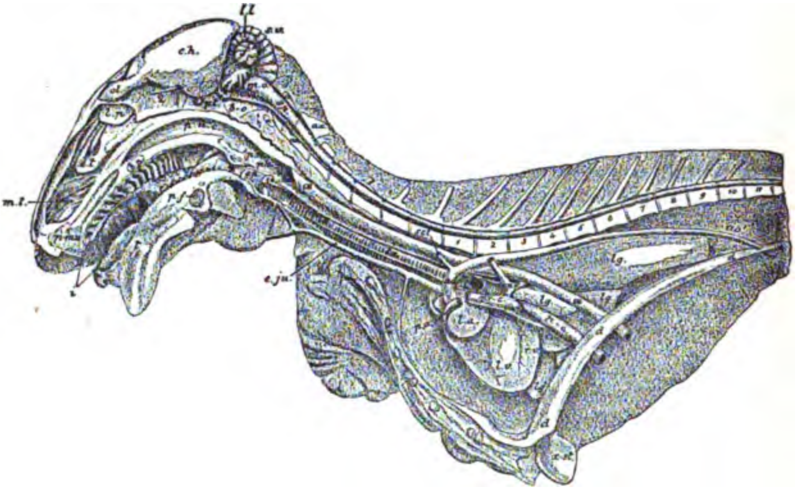

Fig. 148. — General Dissection of Head and Thorax of Rabbit (reduced).—*a*, Atlas; *ax*, axis; 1 *to* 11, placed on centra of thoracic vertebræ; *b-o*, basi-occipital; *pt*, is placed on basi-sphenoid, and 2, on pre-sphenoid; *l.p*, lamina perpendicularis; *e-t*, ethmo-turbinal, and *m-t*, maxillo-turbinal, of right nasal cavity, the turbinal bones of left cavity having been removed and the septum nasi cut through; *p-mx*, pre-maxilla; *b.p*, bony palate; *x-st*, xiphisternum; *d*, *d*, *d*, diaphragm; *i*, incisors; *t*, tongue; *p.f*, papilla foliata, above which is seen a circumvallate papilla; * placed just below tonsil; *ph*, pharynx; *p.n*, internal nares, the opening of *p.n.c*, the posterior nasal chamber, which is mostly floored by soft palate—the letter *n* is placed just under Eustachian opening; *œ*, œsophagus; *l.a*, left auricle; *l.v* and *r.v*, left and right ventricles; *pr-c*, left pre-caval; *e.ju*, right external jugular, formed in front by union of facial veins, and running back to help to form right pre-caval; *p-c*, post-caval; *ao*, arch of aorta—left common carotid is seen running forwards along trachea (*tr* is placed just above it); *s-cl*, left subclavian artery; *ao′*, dorsal aorta; *pa* and *pv*, pulmonary artery and veins—left lung has been removed; *ep*, epiglottis; ×, placed on vocal chord; *tr*, trachea; a little way behind *ao*, opening of right bronchus, end of trachea, and left bronchus cut open, are seen; *lg*, *lg*, *lg*, *lg*, lobes of right lung; *ol*, olfactory lobe, below which is cribriform plate; *c.h*, cerebral hemisphere; *s.v*, *l.l*, and *f*, superior vermis, lateral lobe, and flocculus of cerebellum; *m.o*, medulla oblongata—in front of these letters are the roots of the eighth, seventh, and fifth cranial nerves; *op*, optic nerve; *sp*, spinal cord.

are worn away at their ends. This is called growth from "permanent pulps."

In the front of the upper jaw two strongly curved incisors (*i*) are found, grooved in front, and with chisel-shaped edges. Two very small incisors of similar shape are placed between them and the elevation at the sides of which the naso-palatine canals open. All the upper incisors are imbedded in the pre-maxillæ. The jaw-margin now exhibits a *diastema*, or gap destitute of teeth, on either side, posterior to which are six prismatic grinding teeth, imbedded in the maxilla. The first three, *premolars*, are preceded by milk-grinders, the last three, *molars*, have no predecessors. The grinding teeth are much flattened, and, with the exception of the first and last, which are small, each possesses a deep groove on its outside, from the end of which a transverse ridge runs nearly across the flattish grinding surface or *crown*.

Two *incisors* similar to the large upper ones, but less curved and not grooved, are imbedded in the front of the mandible. Then comes a diastema on either side, succeeded by five grinding teeth, of which two are *premolars*, and three *molars*. They are similar to the upper grinders, but, except the last, more strongly ridged, and grooved internally as well as externally.

In many animals four pointed *canine* teeth are present, two above, immediately behind the pre-maxillo-maxillary suture, and two below. There is no trace of these in the Rabbit.

It is convenient to express the number and kind of teeth by a *dental formula*. Each kind is indicated by a fraction (preceded by its initial letter), in which the numerator and denominator signify upper and lower teeth, those of opposite sides being separated by dashes. Thus the Rabbit's dental formula is:—

$$i = \frac{2-2}{1-1} \quad c = \frac{0-0}{0-0} \quad p.m. = \frac{3-3}{2-2} \Big| \, m. = \frac{3-3}{3-3} = 28.$$

Those before the vertical line have predecessors in the milk-dentition. As, however, the teeth of one side only need be expressed, those of the other exactly corresponding, and the kinds are easily remembered, the formula may be simplified to:—

$$\frac{2 \cdot 0 \cdot 3 \mid 3}{1 \cdot 0 \cdot 2 \mid 3}.$$

The soft palate hangs down behind, and imperfectly separates the mouth-cavity from the *pharynx*, a small chamber which passes back into the œsophagus. An unpaired oval opening, the *internal naris*, opens into it in front, and on its floor, at the root of the tongue, is the *glottis*, guarded in front by a thin flexible flap, the *epiglottis* (*ep*), supported by cartilage. The *œsophagus* (*œ*) is a narrow thick-walled tube, which runs from the pharynx through the neck and thorax, just ventral to the backbone, pierces the diaphragm, and enters the *stomach*. This is a large, transversely placed sac, with firm thick walls. Its left *cardiac* portion is much dilated, while its right *pyloric* portion is thickened. Posteriorly it presents a convex margin, the *greater curvature*, and anteriorly a concave margin, the *lesser curvature*, to the left of which is the *cardia*, or opening of the œsophagus. The *pylorus*, where the duodenum commences, is at the extreme right of the pyloric end. The mucous membrane lining the stomach is raised into irregular longitudinal ridges, or *rugæ*. Between stomach and duodenum there is an inwardly projecting rim, the *pyloric valve*. The stomach is succeeded by a much convoluted intestine, some 15 or 16 times the length of the body, and divided into small and large. The first part of the thin-walled *small intestine*,* the *duodenum*, forms a longitudinally directed U-shaped loop nearly the length of the abdominal cavity. It passes insensibly into the much longer *ileum*, in which here and there are oval thickenings, *Peyer's patches*. This part of the intestine finally opens into the cæcum (*see below*), and at this point its wall is much thickened to form the *sacculus rotundus*. The mucous membrane of the small intestine is raised into numerous irregular transverse ridges, the *valvulæ conniventes*, from which project an immense number of *villi*.

The *large intestine* is divided into cæcum, colon, and rectum. The *cæcum* is a very large thin-walled sac, nearly two feet in length, interposed between the ileum and colon. Its wall is marked externally by a spiral groove. One end, near which the ileum opens, is continuous with the colon, while the other terminates blindly in a thick-walled finger-like *vermiform appendix*. A spiral fold, corresponding to the external groove, projects into the cavity of the cæcum, with which cavity the sacculus rotundus communicates by a small rounded aperture (ileo-colic valve), and which opens by a larger aperture into the colon. The lining mucous membrane is raised into minute elevations; in other words, is *papillose.*

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* In human anatomy this is divided, somewhat arbitrarily, into three parts—*duodenum*, *jejunum*, and *ileum*. The two last are here included in the term "ileum."

The *colon* is a moderate-sized thin-walled tube with baggy walls, along which three smooth longitudinal bands run. It passes insensibly into the narrow *rectum*, which, after some convolutions, runs back within the pelvic cavity, below the backbone, and above the urogenital organs, to the *anus.* The mucous membrane lining the colon is papillose, that lining the rectum is smooth at first, but raised into prominent longitudinal ridges near the end (*see Fig.* 151).

The following large glands are connected with the alimentary canal—salivary glands, liver, pancreas, and rectal glands.

Four pairs of *salivary glands* open into the mouth-cavity. (1.) The *parotid glands* are irregular pinkish masses, extending, on either side, from the origin of the pinna to the hinder end of the mandible. From each a delicate (Stenson's) duct runs forwards just below the skin, turns inwards, and opens into the side of the mouth-cavity opposite the last upper molar. (2.) The *sub-maxillary glands* are oval and compact bodies, of reddish colour, lying near together between the rami of the mandible, in front of the larynx. A delicate (Wharton's) duct runs from the outer side of each to the floor of the mouth, in front of the tongue. (3.) The small red *sub-lingual glands* are elongated and flat. They lie in front of and above the sub-maxillary glands among the muscles of the tongue. From each a fine duct runs forwards to open on the front part of the mouth-floor. (4.) The *infra-orbital glands* are irregular and lobulated. They lie, one on either side in front of and below the eye, partly within the orbit. A duct runs downwards from each and opens into the side of the mouth-cavity, opposite the last upper premolar.

The *liver* is a very large reddish-brown organ, closely applied to the concave abdominal side of the diaphragm in front, and largely overlapping the stomach behind. Right and left halves may be distinguished. The former is divided into two lobes, *right central,*—and *caudate*, hollowed out for, and abutting against, the right kidney. The left half is divided into three lobes, *left central, left lateral*, and the very small *Spigelian*, fitting into the anterior concavity of the stomach. A pear-shaped, thin-walled *gall-bladder* lies in a slit on the posterior surface of the right central lobe. From it a short *cystic duct* opens into the *bile-duct*, a small tube formed by the union of *hepatic ducts* from the various liver-lobes, and opening into the duodenum a little way beyond the pylorus.

The *pancreas* is not compact as in the Frog and Pigeon, but *diffuse*—*i.e.*, made up of numerous scattered lobules. These resemble small masses of fat, and are found in the mesentery between the limbs of the U formed by the duodenum. Delicate ducts proceed from the various lobules, and by their successive unions the *pancreatic duct* is formed, which opens into the distal limb of the duodenum, about three inches from the bend.

The *rectal glands* (Fig. 151, *r.gl*) are two compact elongated bodies lying alongside and above the rectum near its termination, and opening into it.

Histology.—The alimentary canal is lined as usual by *mucous membrane*, outside which is a *muscular coat*, and, in the abdominal organs, there is a thin *serous layer* outside all.

The *mucous membrane* consists of *epithelium* internally, which, as far as the stomach, is *stratified squamous*, but in that organ and the intestines, *simple columnar*. *Goblet cells* are everywhere common, *peptic glands* are found in the stomach, and *glands of Lieberkühn* throughout the intestines. Each peptic gland opens on the surface of the stomach by a narrow *neck*, lined with columnar epithelium. It branches at its deep end, and the branches are lined by granular cuboid *chief cells*, among which are scattered (in the glands of the *cardiac* end) a much smaller number of *ovoid cells*. Beneath the epithelium is a layer of connective-tissue, with blood-vessels, lymphatics, and nerves, the centre of which is traversed (in the stomach and intestines) by a very thin sheet of unstriated muscle, the *muscularis mucosæ*.

The *muscular coat* varies very much in thickness, attaining its maximum in the stomach. It consists of an inner circular and an outer longitudinal layer in the œsophagus and succeeding parts. The fibres are striated in the œsophagus and pharynx, and the tongue is mainly composed of such fibres; but the muscle in the walls of the stomach and intestines is made up of unstriated fibres.

The *salivary glands* and *pancreas* consist of a number of *lobules* united together by connective-tissue. Each lobule is composed of numerous *acini*, spheroidal sacs lined by glandular epithelium, from each of which a duct, lined by simple columnar epithelium, proceeds. These ducts unite again and again to form the main duct of the gland. The preceding type of structure is termed *racemose.*

The **liver**, as in the Frog and Pigeon, is mainly made up of polyhedral, granular *hepatic cells* (Fig. 149), placed in the meshes of the network formed by the *bile-capillaries*, from which the hepatic ducts arise. The hepatic cells are aggregated into small *lobules*, around each of which is an *interlobular* capillary network formed by the ultimate branches of the portal vein. From this network veinlets pass into the centre of the lobule, and there unite into a small *intralobular* vein which carries away its blood. By the union of these small vessels *sublobular* veins are formed. These are the factors of the *hepatic veins.*

5. Circulatory Organs.—Well developed *blood* and *lymph systems* are present.

(1.) **Blood System.**—The *blood* differs from that of the Pigeon (*comp. p.* 294), in the nature of the *red corpuscles,* which are circular, flattened, and *non-nucleated.*

The conical *heart* (Fig. 148) enclosed in its *pericardium*, lies between the lungs on the ventral side of the thoracic cavity, with

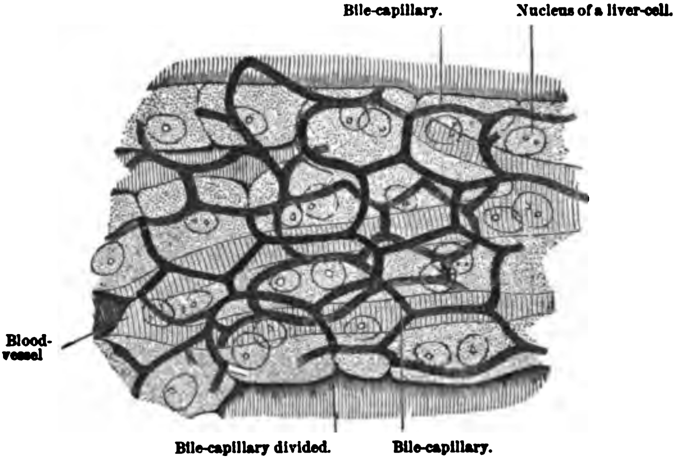

Fig. 149.—HISTOLOGY OF RABBIT'S LIVER (from *Landois* and *Stirling*, after *Hering*).—Relation of liver-cells, bile-capillaries, and blood-capillaries.

its apex directed backwards. The broad base is occupied by the dark, thin-walled *right* and *left* (*l.a*) *auricles*, to each of which is attached a plaited fold, the *auricular appendix*, while the rest of the heart is made up by the firm *right* and *left* (*l.v*) *ventricles*. The internal structure of the heart is in most particulars like that of the Pigeon (*p.* 294), but the right auriculo-ventricular valve is not muscular but made up of three membranous flaps (giving the name *tricuspid valve*), connected by chordæ tendineæ with papillary muscles in the right ventricle. These muscles are also found in the left ventricle, and are more numerous than is the case in the Pigeon.

Arteries.—The *aorta* takes origin from the left ventricle, and its arch (*ao*) curves round to the *left* to form the dorsal aorta. Near the beginning of the arch a short *innominate artery* runs off, which at once gives off the *left carotid* (*running along trachea, tr*), and soon after divides into *right subclavian* and *right carotid* arteries. The *left subclavian* (*s-cl*) arises from the left side of the arch. Each carotid runs forwards on one side of the trachea, giving off branches to the neck as it does so, and divides in front into *internal carotid* for the brain, and *external carotid* for the outside of the head. The subclavian arteries supply the fore-limbs, on entering which they become the *brachial* arteries. A *vertebral* artery runs dorsalwards from each subclavian near its commencement, and enters the vertebrarterial canal to supply the brain and spinal cord.

The dorsal aorta gives off in the thorax small paired *intercostal* arteries to the thoracic walls. In the abdomen a large unpaired *cœliac* artery takes origin a little way behind the diaphragm, and quickly divides into the *hepatic* artery for the liver, and *lieno-gastric* artery for the spleen and stomach. Another unpaired artery, the *anterior mesenteric*, for the small intestine, pancreas, cæcum, and colon, arises a short distance posterior to the cœliac. Paired *renal* (not at same level) and *spermatic* (or *ovarian*) are next given off to the kidneys and testes (or ovaries), and still further back a small unpaired *posterior mesenteric* artery to the rectum. The dorsal aorta bifurcates at the posterior end of the abdominal cavity into the *iliac* arteries, each of which, after giving off an *ilio-lumbar* artery to the body-wall, divides into an *internal iliac* artery for the pelvic region and an *external iliac* artery, which, after giving off a branch that supplies the bladder (and uterus in the female), enters the thigh as the *femoral* artery for the hind-limb.

Shortly before the aorta bifurcates, it gives off from its upper surface a small *median sacral* artery, which runs back into the tail.

The *pulmonary* artery (*pa*) arises from a forward prolongation of the right ventricle on the ventral side, and, curving round the front of the heart, divides into right and left branches for the corresponding lungs.

Veins.—Caval, hepatic portal, and pulmonary systems can be distinguished.

Caval System.—Right and left (*pr-c*) precavals and a postcaval (*p-c*) carry the impure blood from the general system into the right auricle. Either *precaval* is formed by the union of an *external jugular* (*e.ju*), with a *subclavian* vein. The former runs back along the side of the neck from the angle of the jaw, where it is formed by the union of *facial* veins returning blood from the outside of the head. Just before uniting with the subclavian it receives the small *internal jugular* vein from the brain. The *subclavian* vein brings back blood from the fore-limb. The *right* precaval is joined by an unpaired *azygos* vein, which lies just beneath the vertebral column in the thorax, and carries off blood from a large part of its walls.

The *postcaval* (*p-c*) is a very large vein formed at the posterior end of the abdomen by the union of the *internal iliac* veins from the backs of the thighs. It is joined almost at once by the *external iliac* veins, which return blood from the hind-limbs and bladder (also uterus in the female). They are direct continuations of the *femoral* veins of the thighs. The postcaval runs forwards in the abdomen close to and on the right of the aorta, receiving successively *ilio-lumbar*, *spermatic* (or *ovarian*), and *renal* veins, from the body-walls, testes (or ovaries), and kidneys respectively. Before reaching the diaphragm it turns ventralwards, runs through the dorsal part of the liver (from which it receives four chief *hepatic veins*), and pierces the diaphragm ventral to the œsophagus. In the thorax it runs forwards between the lungs and finally enters the right auricle.

Hepatic Portal System.—The *portal* vein is formed by the union of *lieno-gastric*, *duodenal*, *anterior mesenteric*, and *posterior mesenteric* veins, which return blood from the stomach and spleen—duodenum and pancreas—ileum and most of large intestines—and last part of rectum, respectively. The portal vein soon divides into branches, which break up in the various liver-lobes.

Pulmonary System.—There are two *pulmonary* veins (*p.v*) from either lung. All four open into the dorsal side of the left auricle.

(2.) **Lymph System.**—The *lymph*, as in other cases, resembles blood, were it not for the absence of red blood-corpuscles. Both *lymphatics* and *lacteals* are well defined, and a single *thoracic duct* is present, lying above the dorsal aorta. Its posterior end receives the lacteals, while anteriorly it opens into the junction between the left subclavian and external jugular veins. Some of the lymphatics unite to form a much smaller trunk, opening similarly on the right side.

Numerous small *lymphatic glands*, which resemble the cervical glands of the Pigeon, are present in various situations.

An elongated flattened *spleen*, of a dark-red colour, is attached by a flap of mesentery to the cardiac end of the stomach.

The *thymus gland* is a fat-like mass, largest in young animals, closely connected with the base of the heart. The *thyroid gland* consists of two small flattened lobes of brownish colour, closely applied to the sides of the larynx, and connected together by a ventral bridge of tissue.

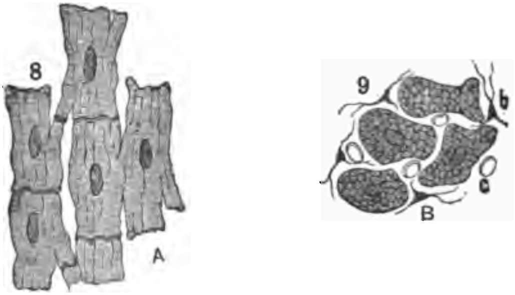

Fig. 150.—Muscle-Fibres from Mammalian Heart (from *Landois* and *Stirling*), much enlarged.—9 in cross-section.

Histology (*comp. p.* 249).—The muscle of the *heart* (Fig. 150) is composed of transversely-striated fibres, devoid of sarcolemma, which are united into a close network. This is marked into short lengths corresponding to the constituent cells, and in each of these a muscle-corpuscle, not placed superficially, is imbedded. The *veins* contain numerous valves, which are flap-like projections of their inner coat. The lymphatics and lacteals possess well-defined walls, resembling those of small veins. A great many valves are developed in their course.

6. Respiratory Organs (Fig. 148).—The slit-like *glottis*, at the base of the tongue, which is guarded in front by the *epiglottis* (*ep*), leads into the *larynx*. This is supported by a broad *thyroid cartilage* (which is a bent plate, incomplete dorsally), and, posterior to this, by a ring-like *cricoid cartilage*, the dorsal side of which is thickened. Two elastic folds, the *vocal chords* (×) project from the sides of the larynx. They are attached below to the thyroid cartilage, above to two small *arytenoid cartilages*, which articulate dorsally with the front edge of the cricoid. The larynx may be regarded as the modified top of the *trachea* (*tr*), which runs along the neck ventral to the œsophagus. It is supported by rings of cartilage, which are incomplete dorsally. The trachea bifurcates within the thorax, just anterior to the base of the heart, into two *bronchi*.

The *lungs* (*l*,*l*) are two spongy bodies, pink in colour, which mainly fill the thoracic cavity, as long as its walls remain intact. The left lung is subdivided into two, the right lung into four *lobes* of very unequal size. Each lung is enveloped by a delicate membranous *pleura*, which consists (like the peritoneum) of a *visceral* layer, closely applied to the surface of the lung, and a *parietal* layer, lining one half of the thorax. The two layers are continuous at the root of the lung. The parietal layers of the two pleuræ meet together in the middle line to form, in the posterior part of the thorax, a longitudinal vertical partition, the *mediastinum*. The two sheets of which this is composed diverge further forwards, and leave between them the *mediastinal space*, occupied by the heart in its pericardium. The bronchi enter the anterior ends of the lungs, and, like the trachea, are supported by cartilage. Each of them forms a *bronchial tree* in its lung by giving off alternating right and left branches.

Most of these are given off *below* the pulmonary artery—*i.e.*, are *hyparterial*.

The *diaphragm* is a thin partition which forms the posterior boundary of the thorax, and separates it from the abdomen, towards which it is concave when at rest. The centre of the diaphragm is transparent and tendinous (*i.e.*, composed of white connective-tissue fibres), while its margins are muscular, especially on the dorsal side, where they are continued into two muscular *pillars*, which take origin on the under sides of the lumbar vertebræ.

Histology.—The branches of the bronchial tree divide repeatedly (the supporting cartilages being at the same time gradually lost), to form delicate *bronchial tubes.* These end in clusters of dilations, the *infundibula*, with sacculated walls. They are lined by simple squamous epithelium, beneath which is a very rich network of capillaries. The trachea and larger air-passages are lined by stratified columnar epithelium, ciliated in part.

The lungs contain a large quantity of elastic connective-tissue and unstriated muscle.

7. Excretory, and 8. Reproductive Organs (Fig. 151).—In both sexes two oval, compact, reddish-brown *kidneys* are closely applied to the dorsal wall of the abdominal cavity, the right rather further forwards than the left. They are covered ventrally by peritoneum.

Each kidney (C) presents a notch, the *hilus*, on its inner margin, from which the *ureter* (*ur*), a narrow tube with muscular walls, proceeds. The ureters open obliquely into the dorsal side of the pear-shaped *urinary bladder* (*u.b*), towards its narrow portion or *neck.* The walls of the bladder are translucent and muscular. It projects into the body-cavity just in front of the symphysis pubis.

A median horizontal section of either kidney shows that it is differentiated into a marginal *cortex* (*co*), dark-red in colour, with numerous small dots (Malpighian bodies), and a central paler *medulla* (*md*), which presents a striated appearance. The striæ converge internally towards a conical eminence, the *urinary pyramid* (×),which projects into the *pelvis,* or dilated end of the ureter.

Male Reproductive Organs (A).—The oval *testes* (*t*) are contained in the *scrotal sacs,* which in the breeding-season project on either side of the urogenital aperture. Each sac is covered externally by skin, internal to which are layers of connective-tissue, muscle, and peritoneum successively. The testis is attached to the sac by a short fibrous cord, the *gubernaculum* (*gu*), at its posterior end, and is also suspended by a *mesorchium*. Attached to the testis is a compact mass of coiled tubules, the *epididymis*, divided into the

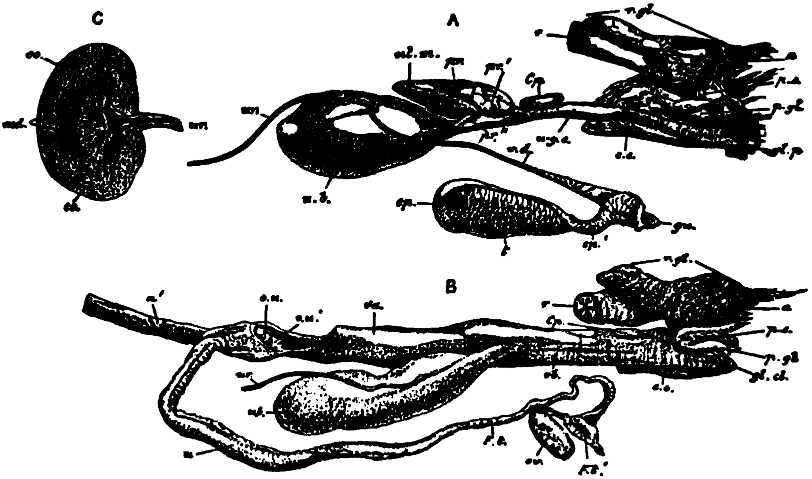

Fig. 151.—Urogenital Organs of Rabbit.—A, male; B, female; C, horizontal section of right kidney; *co* and *md*, cortex and medulla of kidney (in C); ×, placed on urinary pyramid; *ur*, ureter; *u.b*, urinary bladder; *r*, rectum; *r.gl*, rectal gland; *a*, anus; *p.s*, perineal space; *p.gl*, perineal gland (in *A*, the aperture is shown by a dot); *t*, testes; *ep* and *ep'*, caput and cauda epididymis; *gu*, gubernaculum; *v.d*, vas deferens; *ut.m*, uterus masculinus; *pr*, *pr'*, and *pr''*, lobes of prostate; *u-g.c*, urogenital canal; *c.c*, corpus cavernosum; *gl.p*, glans penis; *ov*, left ovary; *F.t*, left Fallopian tube; *F.t'*, funnel of ditto; *u*,*u'*, left and right uteri, the latter cut short; *o.u* and *o.u'*, the mouths of the left and right uteri, to show which the vagina, *va*, has been cut open; *vb*, vestibule; *gl.cl*, glans clitoridis.

caput epididymis (*ep*) in front, and the *cauda epididymis* (*ep'*) behind. These cap the anterior and posterior ends of the testis, and are connected by a tubule running along its surface.

The *spermatic artery* and *vein* are connected with the anterior end of the testis. They form, with nerves, connective-tissue, &c., the *spermatic cord*.

The *vas deferens* (*v.d*) proceeds from the cauda epididymis, runs forwards, and then curves over the ureter to open into the *uterus masculinus* (*ut.m*), a large, slightly bilobed sac, lying dorsal to the neck of the bladder. This last narrows into a *urogenital canal* (urethra) lying between the rectum and the ilio-pubic symphysis (*ug.c*). Behind this the canal traverses the *penis*, an elongated backwardly-directed structure, the ventral side of which is strengthened by two fibrous rods, the *corpora cavernosa* (*c.c*) attached in front to the ischia. The dorsal side of the penis is made up of a mass of vascular tissue, the *corpus spongiosum*, through which the urogenital canal runs, and which projects beyond the corpora cavernosa to form the *glans penis* (*gl.p*), a soft conical body, forming the free end of that organ, and invested in a loose fold of skin, the *prepuce*. Upon the glans penis is a slit, the *urogenital aperture*.

The uterus masculinus opens into the dorsal side of the urogenital canal, a little way behind the neck of the bladder, by a crescentic aperture placed immediately in front of the *verumontanum*, an oval papilla which projects into the canal. The dilated ends of the vasa deferentia run close together between the bladder and uterus masculinus, and open into the ventral wall of the latter just in front of its own aperture mentioned above. Closely attached, dorsally and laterally, to the uterus masculinus is the *prostate gland*, made up of anterior (*pr*), posterior (*pr′*), and small lateral lobes (*pr″*), all of which open into the urogenital canal by minute slits at the sides of the verumontanum. A pair of small oval bodies, *Cowper's glands* (*Cp*), are situated on the dorsal side of, and open into, the urogenital canal behind the prostate.

Female Reproductive Organs (B).—The *ovaries* (*ov*) are whitish, oval bodies, placed one on either side of the dorsal abdominal wall, posterior to the kidneys. In a mature female, *Graafian* (ovarian) *follicles* appear as clear, rounded projections on their surfaces. Near each ovary is the funnel-shaped opening (*F.t′*) of a narrow convoluted *Fallopian tube* (*F.t*), which merges into a cylindrical *uterus* (*u*), with thick muscular walls. This may be of very large size in the pregnant female, and it then exhibits a series of oval swellings, in each of which an embryo is contained. The two uteri open by separate apertures (*o.u* and *o.u′*), *ora uterorum*, with rounded projecting margins, into the *vagina* (*va*), a large tube which runs back dorsal to the bladder, with the neck of which it unites to form the *urogenital canal* (vestibule), a somewhat smaller but still wide tube (*vs*), which runs back in the same position as the narrow urogenital canal of the male. The walls of the tube are vascular, and correspond to the corpus spongiosum of the penis. It ends in an elongated *urogenital aperture*, or *vulva*. Imbedded in the ventral wall of the vestibule is a small elongated body, the *clitoris*, supported by *corpora cavernosa* (*c.c*), similar to, but very much smaller than, those of the penis, and similarly situated. The clitoris ends in a soft, flattened *glans clitoridis* (*gl.cl*). Small *Cowper's glands* (*Cp*) open into the dorsal wall of the vestibule.

Histology.—**Kidney** (Fig. 152).—The *uriniferous tubules* are substantially similar to those of the Pigeon (*p.* 300), but more complicated. Each commences with a *Bowman's capsule*, which with its *glomerulus* (*i*) constitutes a *Malpighian body*, and is situated in the cortex. The *neck* of this passes into a thickened *glandular part* (*x*, *x*, *x*), also in the cortex, from which a narrow part (*t*) runs into the medulla, and then loops back into the cortex to dilate into a second *glandular part* (*n*, *n*, *n*), which passes into a collecting part (*o*, *o*). The collecting parts run towards the urinary pyramid, often uniting in their course, and finally open upon it (O).

The *renal artery* divides within the kidney, and from its branches (*r*) small *afferent arteries* (1) run to Bowman's capsules and break up into *glomeruli*. A small *efferent vein* (2) arises from each glomerulus. The efferent veins now break up into a network of capillaries (A) surrounding the glandular parts of the tubules. The factors (V, V) of the *renal vein* take origin in this network.

The *testis* is essentially composed of *seminiferous tubules* lined by germinal epithelium, the cells of which divide frequently to form spermatozoa, each producing several, but not being entirely used up in the process (*compare preceding forms*). The *spermatozoa* have oval flattened *heads* and vibratile *tails*. The tubules of the testis unite to form *vasa efferentia*, which make up the epididymis.

The *ovary* consists of Graafian follicles in various states of development imbedded in a connective-tissue basis or *stroma*. The mature follicles project from the surface of the ovary, and each, when mature, is a fluid-containing vesicle, the walls of which are made up of two or more layers of columnar epithelial cells. The ovum is placed on the outer side, and is surrounded

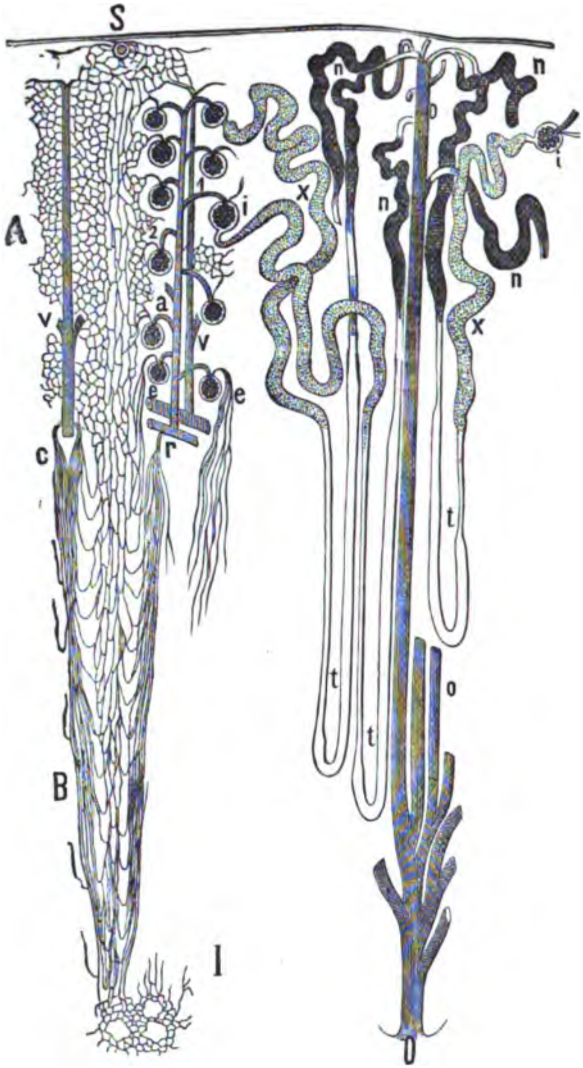

Fig. 152.—Diagram of Blood-vessels and Uriniferous Tubules of Kidney (from *Landois* and *Stirling*).—A and B, Capillaries of cortex and medulla. On the left numerous glomeruli are shown with (1) afferent artery; (2), efferent vein. The glomeruli are enclosed in Bowman's capsules. *x*, *x*, *x*, and *n*, *n*, *n*, glandular parts, and *o*, *o*, *o*, collecting parts of tubules; O, Opening on urinary pyramid.

by several layers of these cells, with which it forms a mass, the *discus proligerus*, that projects into the cavity of the follicle. The ripe *ovum* is invested by a radiately striated membrane, the *zona radiata*, but no distinct traces remain of the *vitelline membrane* present in the young ovum. The *vitellus* contains hardly any food-yolk, and within it is a large *germinal vesicle* with *germinal spot*.

9. Muscular System (*compare p.* 254).—The muscles are very numerous and arranged in a very complicated manner. The voluntary muscles are from their appearance divided into *red* and *white*. The darker colour of the former is due to their richer blood-supply.

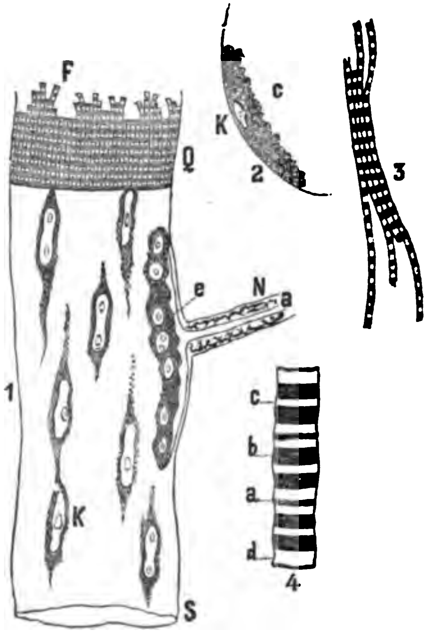

Fig. 153.—HISTOLOGY OF STRIATED MUSCLE (from *Landois* and *Stirling*), all much enlarged.—1. Part of a fibre—Q, transverse striations; F, primitive fibrillæ; K, muscle-corpuscles; S, sarcolemma; N, an entering nerve-fibre, with *a*, axis cylinder, and *e*, end-plate. 2. Part of a fibre in cross-section—K, muscle-corpuscle. 3. Primitive fibrillæ.

Histology (Fig. 153).—The striated muscle-fibres are smaller than those of the Frog, and the *muscle-corpuscles* are situated superficially, just beneath the sarcolemma. The fibres of the *red* muscles are larger than the rest.

10. Nervous System (Fig. 148)—**Cerebro-Spinal Axis.**—For investments *compare p.* 254. The **brain** is elongated, but is not particularly well-developed.

Fore-Brain.—The *thalamencephalon* presents the usual structure, but two parts not present in preceding types are here seen. One is the *middle commissure*, a broad band of grey matter connecting the side-walls of the third ventricle between the anterior and posterior commissures. The other is a rounded eminence, the *corpus mammillare*, seen on the under surface immediately behind the *pituitary body* (*pt*) which is attached as previously to the *infundibulum*. With the hinder part of the thin roof of the third ventricle the *pineal gland* is connected by a hollow bifurcated stalk.

The *cerebral hemispheres* (*c.h*) are broad behind and taper in front to blunt points. Externally they are almost smooth, but each is divided by grooves into three lobes, *frontal*, *parietal*, and *temporal*, placed respectively in front, postero-dorsally and postero-ventrally. As in the Frog and Pigeon the hemispheres are closely applied in the middle line, but are, in addition, firmly united by an elongated band of transverse fibres, the *corpus callosum*. Below this and continuous with it behind is another fibrous band, the body of the *fornix*, which divides in front into four smaller bands, the *pillars* of the fornix. Two of these, the *anterior pillars*, pass downwards in the lamina terminalis and substance of the optic thalami to reach the corpus mammillare, while the other two, *posterior pillars*, curve outwards into the hemispheres. Each *lateral ventricle* is divisible into three parts—a narrow *anterior cornu* in front, and towards the inner side, a *posterior cornu*, similarly placed behind, and a *descending cornu*, which passes down into the temporal lobe. A prominent oval mass, the *hippocampus major*, projects into the last-named cornu, and along the anterior edge of this the posterior pillar of the fornix runs. In front of this pillar there is a vascular fold, the *choroid plexus*, which extends into the ventricle from the pia mater. The *corpus striatum* forms the outer side and floor of the anterior cornu. The cerebral hemispheres fuse where they meet in front of the lamina terminalis, and form a party-wall, the *septum lucidum*, to the hinder parts of the anterior cornua, immediately in front of the foramen of Munro on either side. This partition is not solid, but contains a small slit-like *fifth ventricle.*

This is not, therefore, like the other ventricles, a part of the cavity of the original neural tube of the embryo. These were originally named 1st and 2nd (*i.e.*, the two lateral), 3rd and 4th ventricles, and when another brain-cavity was discovered it naturally received the name 5th ventricle.

The *olfactory lobes* (*o.l*) are elongated and dilated at their ends. They are attached to the under sides of the frontal lobes, and run forwards in front of them to rest on the cribriform plate. Each contains a small *olfactory ventricle* continuous with the corresponding anterior cornu.

The *mid-brain* is traversed by the *Sylvian aqueduct.* Above it presents the *optic lobes*, which are overlapped by the cerebral hemispheres. Each of them is subdivided into two, so that there are *four* elevations, two anterior and larger *nates*, and two posterior *testes.* There are no optic ventricles. Two very distinct longitudinal masses of fibres, the *crura cerebri*, form the floor of the mid-brain.

Hind-brain.—The *medulla oblongata* (*m.o*) presents well-marked *dorsal* and *ventral fissures.* These are bounded by narrow bands, the *dorsal* and *ventral pyramids.* The dorsal pyramids diverge in front and sweep round the sides of the thin roof of the fourth ventricle. On either side of this is a projection, the *corpus restiforme.* On the under surface the ventral fissure and pyramids are interrupted by a broad band of transverse fibres, the *pons Varolii*, just behind the crura cerebri. Immediately behind this there is a rectangular area, the *corpus trapezoideum*, on either side of the ventral pyramid, occupied by transverse fibres.

The *cerebellum* is very large and made up of a median *vermis* (*s.v*) marked by deep transverse furrows, and a pair of much convoluted *lateral lobes* (*l.l*), to each of which a small rounded *flocculus* (*f*) similarly furrowed, is attached. The cerebellum is united to the rest of the brain by three pairs of commissures or *peduncles.* The anterior peduncles connect it with the testes, the middle peduncles with the pons Varolii, and the posterior peduncles with the corpora restiformia.

The **spinal cord** (*sp*) is cylindrical, and possesses dorsal and ventral fissures. There is no sinus rhomboidalis.

Cranio-Spinal Nerves.—There are twelve pairs of *cranial nerves*, as in the Pigeon, which take origin and are distributed in a similar manner. The *olfactory* lobes send numerous fibres through the pores in the cribriform plate to the olfactory mucous membrane. The *optic nerves* (2) form a chiasma, but the optic tracts are relatively narrow. The *trigeminal* nerves arise from the sides of the pons, and the *facial* and *auditory* from the sides of the corpora trapezoidea. The *abducent* nerves come off from the extreme front of the ventral pyramids. The exits of the cranial nerves have already been described (*p.* 324). Outside the skull it may be noted that the *mandibular* ramus of the fifth sends a *lingual* branch to the tongue. The *vagi* run back along the neck by the sides of the common carotids. Each gives off a *superior laryngeal* nerve to the larynx, from which a *depressor* branch runs, closely united with the sympathetic, to the heart. At the posterior end of the neck a *recurrent laryngeal* nerve is given off, which curves round the aorta on the left, or the subclavian on the right, and runs forwards to the larynx. Behind this the vagi run through the thorax and pierce the diaphragm, finally breaking up into branches for the abdominal viscera.

The *spinal* nerves arise by two roots as usual, and are named *cervical*, *thoracic*, &c., according to the region of the vertebral column to which they correspond.

In the *cervical* region the nerves are named from the vertebra, in *front* of which they emerge, but there is an eighth cervical nerve *behind* the last cervical vertebra. In the other regions they are named from the vertebræ, *behind* which they emerge.

The last four cervical and the first thoracic nerves form the *brachial plexus*, from which the fore-limb is supplied, and from which also arises the *phrenic nerve*, which runs back to supply the diaphragm.

The *lumbo-sacral plexus* for the hind-limb is constituted by the last three lumbar and the first three sacral nerves.

Sympathetic System.—This is formed by a ganglionated cord on either side (*comp. pp.* 260 *and* 303) of the body, ventral to the vertebral column. These are connected by *rami communicantes* with the spinal nerves. In the neck there are only two ganglia, the *posterior cervical* at the root of the neck, and the *anterior cervical* placed near and connected with the *vagus ganglion*. In the thorax two large *sympathetic nerves* run off from the cords, and, piercing the diaphragm, fuse with a large *cœliac ganglion,* placed just in front of the origin of the anterior mesenteric artery, and united with a *mesenteric ganglion* just behind it. From these ganglia numerous branches run off to the abdominal viscera.

Histology.—Compare p. 303.

11. **Sense Organs**—(1.) **Tactile Organs.**—Numerous *touch-corpuscles* are present in the skin (*p.* 303), especially at the bases of the vibrissæ.

(2.) **Gustatory Organs.**—Imbedded in the sides of the circumvallate papillæ and papillæ foliatæ are numerous *taste-buds,* containing elongated *taste-cells,* connected with glossopharyngeal fibres.

(3.) **Olfactory Organs.**—The nasal cavities (Fig. 148) are largely lined by *olfactory mucous membrane,* which extends over the ethmo-turbinals (*e-t*), and contains elongated *olfactory cells* (*comp. Fig.* 125).

(4.) **Auditory Organs.**—The *external ear* consists of a *pinna* and an *external auditory meatus,* closed below by the *tympanic membrane.* This last also forms the upper and outer boundary of the *middle ear* or *tympanic cavity,* which has already been described. The *inner ear* (Fig. 154, C) is, broadly speaking, similar to that of the Pigeon (Fig. 154, B), but the *semicircular canals* are

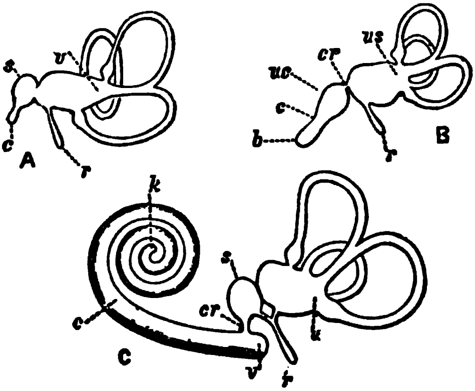

Fig. 154.—Diagrams of the Membranous Labyrinth (from *Haddon*). Internal side of left labyrinth.—B, Bird. C, Mammal; *us*, utriculus and sacculus; *u*, utriculus; *s*, sacculus; *c*, cochlea.

arranged rather differently (the anterior vertical not crossing over the horizontal), the *sacculus* (*s*) and *utriculus* (*u*) do not communicate directly, and the *cochlea* (*c*) is produced into a delicate tube, spirally coiled, and contained within the promontory. A special series of sense cells, forming the *organ of Corti*, is found within the cochlea.

(5.) **Optic Organs** (*see Figs.* 126 *and* 127).—The *eye* and the *eye-muscles* do not differ widely from the condition found in the Frog (*p.* 264). But the sclerotic is not supported by cartilage, and the lens is much flatter (*as in Fig.* 126). The accessory structures, besides muscles, are the *conjunctiva*, three *eyelids*, and *lachrymal* and *Harderian glands*.

PHYSIOLOGY.

1. **Nutrition.**—The *food* consists of vegetable substances, and the great length of the alimentary canal is correlated with this, an immense absorptive surface, largely augmented by the cæcum with its spiral valve, being given.

The food is divided by the incisor teeth, and ground up by the molars and premolars. The hard tongue, working against the ridged palate, assists in this process of mastication. *Saliva* is poured by the salivary glands into the mouth-cavity, and not only lubricates the food, but also, in virtue of a ferment, *ptyalin*, which it contains, converts more or less of the starch into soluble grape-sugar. The *gastric juice*, *bile*, and *pancreatic juice* act as in preceding cases (*p.* 266).

Circulation.—This is effected much as in the Pigeon (*p.* 305), but is less vigorous.

2. **Destructive Metabolism**—(1.) **Respiration.**—Inspiration and expiration are partly effected by movements of the *ribs*, and partly by movements of the *diaphragm*, and respiration is hence said to be both *costal* and *diaphragmatic*.

It must be remembered that each lung is enclosed in an air-tight bag, the *pleura*, and is obliged to follow all the movements of the thoracic walls, or else a vacuum would be formed between the two layers of this. The elastic tissue in the lungs causes them to be always *trying* to contract, but this is prevented by the pressure of the air in the lung-passages. If, however, the pleura is perforated, this pressure is counterbalanced, and the lung at once contracts.

Inspiration.—The ribs and sternum are moved downwards and forwards, and thus increase the dorso-ventral capacity of the thorax. At the same time the muscular parts (especially the pillars) of the diaphragm contract, thus flattening it and increasing the antero-posterior capacity of the thorax.

Air consequently rushes into the larger air-passages from the exterior.

Expiration is the exact converse of this, but is largely passive, the various muscles ceasing to contract. It is aided by the elasticity of the lungs and walls of the thorax. As a result, the air rushes out again.

The air passes *directly* in and out of the *larger* air-passages *only*. The rest is effected by diffusion, and the *essential* part of respiration (exchange of gases) is carried on in the infundibula.

Respiration is less active than in the Pigeon, but here also the body is maintained at a temperature (about 100° F.) much above that of the surrounding medium.

(2.) **Excretion** (*comp. p.* 306).—The nitrogenous waste-products are *urea* (CH_4N_2O) and *hippuric acid* ($C_9H_9NO_3$).

3. Reproduction.—The *ova* burst from their follicles into the body-cavity, and are taken up by the funnels of the Fallopian tubes. *Fertilization* (Fig. 94) is effected in the upper part of these tubes, *polar cells* having previously been formed (Fig. 93). Sperm is ejected by the male into the female passages, the penis being used as a copulatory organ.

4. Contractility, and 5. Irritability and Spontaneity.—The latter is much as in the Pigeon (*p.* 306). The intelligence is, however, greater, and this is correlated with the greater size of the cerebral hemispheres, and their more complete union by the conducting fibres of the corpus callosum and fornix.

DEVELOPMENT.

1. Early Stages.—**Segmentation** (Fig. 155) is complete and almost regular, there being only a very small quantity of food-yolk in the minute ovum to impede it. By successive bipartitions eight cells are produced, four of which are larger than the others, and are called *outer cells*, from their subsequent fate.

The other four are termed *inner cells*, for a similar reason. Both inner and outer cells continue to divide, but the latter increase more rapidly and grow over the others. At the close of segmentation, which takes place in the Fallopian tube, the ovum consists (Fig. 155, *a*) of a layer of clear *outer cells* (*ect*), which cover a central mass of granular *inner cells* (*ent*), except at one point. The ovum is still invested by the zona radiata, external to which is an albuminous coating, the *zona pellucida* (*z.p*), received from the wall of the Fallopian tube. The changes that follow take place in the uterus, and lead to the formation of the embryonic layers.

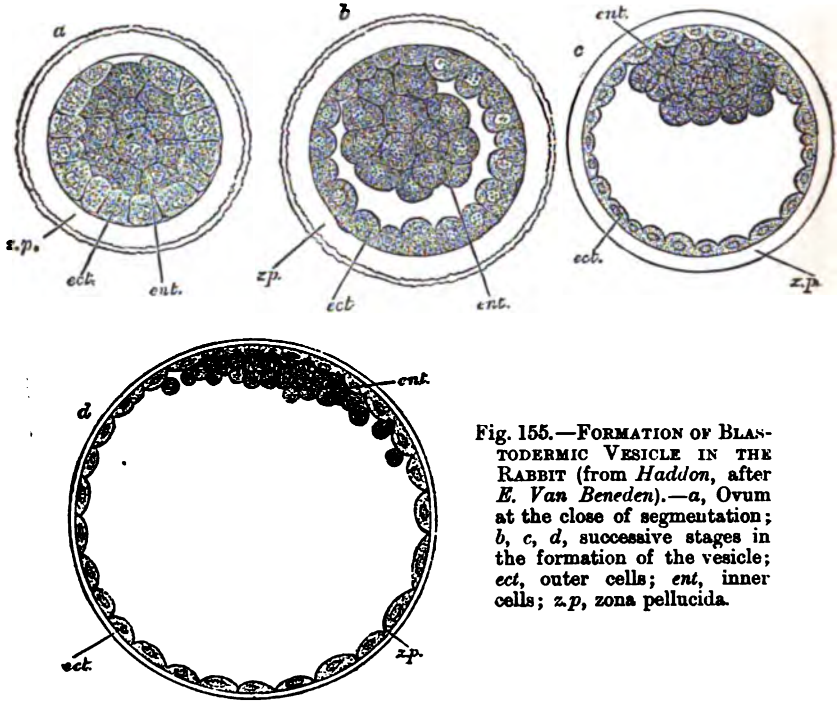

Fig. 155.—FORMATION OF BLASTODERMIC VESICLE IN THE RABBIT (from *Haddon*, after *E. Van Beneden*).—*a*, Ovum at the close of segmentation; *b*, *c*, *d*, successive stages in the formation of the vesicle; *ect*, outer cells; *ent*, inner cells; *z.p*, zona pellucida.

The *outer cells* first of all grow completely over the inner cells, and then increase and become flattened to form the *blastodermic* *vesicle*, an internal cavity forming meanwhile, which gets larger and larger (Fig. 155, *b*, *c*, *d*). The result of these changes is a delicate vesicle (Fig. 155), the walls of which are mainly formed by outer cells (*ect*), to which the inner cells (*ent*) adhere over a small internal area. The blastodermic vesicle continues to increase in size, and the inner cells gradually extend at the edges. In the centre, however, of the patch of inner cells a circular thickening appears (Fig. 156), the *embryonic area* (*ag*), corresponding to the area pellucida of the Chick. The inner cells here become divided into an upper layer of rounded cells and a lower layer of flattened cells. The former unite with the outer cells to form the **epiblast** of the embryonic area, while the latter constitute the **hypoblast** of the same region. *Outside* this the epiblast and hypoblast are formed by the outer and inner cells respectively.

	Embryonic Area.	*Rest of Vesicle.*
Epiblast, .	Outer cells. Rounded inner cell layer,	Outer cells.
Hypoblast, .	Flattened inner cell layer,	Inner cells.

The **mesoblast** is first formed in the embryonic area, and has a double origin similar to that described for the Chick (*p.* 301). A side view of the blastodermic vesicle on the seventh day is shown in Fig. 156.

2. General Growth.—This is essentially the same as in the case of the Chick (*pp.* 310-313). The embryo is formed in the embryonic area (area pellucida), and is at first flattened out on the surface of the blastodermic vesicle, just as the Chick is flattened out on the yolk. But the vesicle only contains *fluid*, there being hardly any food-yolk, and its wall, from the first, is partly formed of epiblast, the other layers subsequently extending into it. In the Chick *all* the layers grow round to invest the yolk, which is at first covered only by the vitelline membrane. The embryo is folded off as described previously for the Chick, and it is only at a comparatively late date that special characteristics are developed. It must, however, be remembered that though four visceral clefts (Fig. 157) are present, the last one is not bounded behind by an arch.

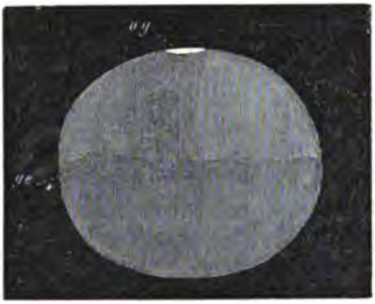

Fig. 156.

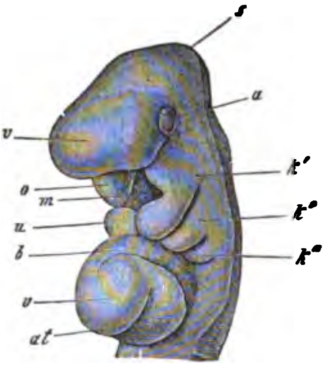

Fig. 157.

Fig. 156.—Blastodermic Vesicle of Rabbit seven days after Fertilization. Side view deprived of its envelopes. Magnified about 10 diameters (from *Haddon*, after *Kölliker*).—*ag*, Embryonic area; *ge*, lower limit of hypoblast; below this line the vesicle consists only of a single layer of epiblast.

Fig. 157.—Head of Ten Day Rabbit (from *Haddon*, after *Kölliker*).—*a*, Eye; *at*, *v*, and *b*, atrium, ventricle, and truncus arteriosus of heart; *v* (upper one) and *s*, fore- and mid-brains; *k′*, *k″*, *k‴*, mandibular, hyoid, and first branchial arches; *o*, superior maxillary process of *k′*; *m*, mouth.

3. Fate of the Germinal Layers.—The **epiblast, hypoblast,** and **mesoblast** give rise to the same parts as in the Chick (*pp.* 313-315), but a few remarks are necessary concerning the *mesoblastic* structures.

Cartilaginous bars are developed in the first three visceral arches, which develope as follows:—

I. *Mandibular*.—Incus, Malleus, and Meckel's cartilage of either side, Eustachian cartilage, Pterygoid, and Palatine.

II. *Hyoid*,	fuse ventrally to form body of hyoid,	anterior cornua.
III. *Branchial* 1,	. . . . .	posterior cornua.

The *aortic arches* develop in a similar way to those of the Chick (*p.* 315), but the *left 4th* arch becomes the *aorta*, and the *right 4th* the *right subclavian*, while the *right 5th* arch disappears, and the *left 5th* forms the *pulmonary artery*.

The *anterior cardinals* become the *external jugulars*, and the *Cuvierian ducts* the *precavals*.

4. **Embryonic Appendages** (Fig. 158).—These are modified in accordance with the important fact, that while in the Chick development mainly goes on outside the parent's body, at the expense of the bulky food-yolk, the embryo Rabbit develops mainly within the body of the mother, and is born alive. In other words, the Bird is *oviparous*, the Mammal *viviparous*.

It must be borne in mind that the blastodermic vesicle is closely invested by the remains of the *zona radiata* of the ovum.

The **yolk-sac** (umbilical vesicle) is formed by that part of the blastodermic vesicle which is outside the embryonic area. From the first its wall is formed within the zona radiata by epiblast, beneath which the other layers grow round. As the embryo is

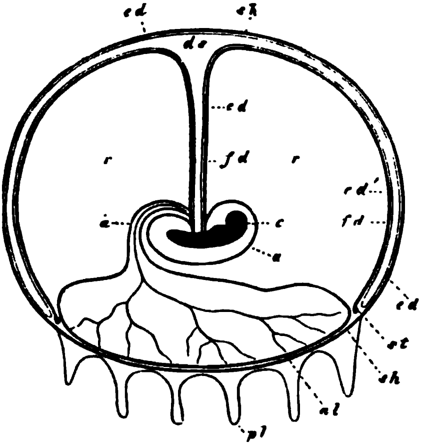

Fig. 158.—Embryonic Appendages of the Rabbit—Diagrammatic longitudinal section (from *Kölliker*, after *Bischoff*).—*c*, Embryo; *a*, amnion, and stalk of allantois (*al*); *sh*, subzonal membrane; *pl*, placental villi; *fd* and *ed*, vascular and hypoblast layers of yolk-sac; *ds*, placed in narrow cavity of yolk-sac; *r*, space filled with fluid.

folded off, the yolk-sac comes to form a ventral appendage to its body. A yolk-sac blood-circulation is established, and this appendage becomes much flattened and shaped like an umbrella, with the handle attached to the embryo (Fig. 158).

The **amnion** is formed as in the Chick (Fig. 145), but there the outer limbs of the folds contain epiblast and mesoblast, and, with the epiblast and somatic mesoblast of the yolk-sac, with which they are continuous, fuse with the vitelline membrane. Here the outer limbs of the folds contain *epiblast* alone (probably), and are continuous with the *epiblast* of the yolk-sac, which splits off. This continuous layer of epiblast forms a *subzonal membrane* (*sh*), which lines the zona radiata. To this membrane the flattened yolk-sac attaches itself closely over a large area.

The **allantois** (*al*) (*comp. Fig.* 145) grows out from the hinder end of the alimentary canal, and becomes closely united with the subzonal membrane for a small circular area on the dorsal side of the embryo, to which it remains attached by a narrow stalk. From this area numerous slender processes, *villi* (*pl*), grow out, which fit into depressions in a corresponding area of the uterine mucous membrane, which becomes thickened and vascular. A blood-circulation is developed in the allantois, and blood-vessels extend into the villi. Ultimately close union takes place between the villi and the wall of the uterus. A circular flattened structure, the *placenta*, is thus formed, consisting of an embryonic part, mainly formed by the allantois, and a *maternal* part, constituted by the thickened area of the uterine mucous membrane. The placenta is connected with the embryo by the stalk of the allantois (*a*) and certain structure which surround and form with it the *umbilical cord.* The impure blood of the embryo passes into the embryonic part of the placenta by two *allantoic* arteries which break up into branches, and, in the villi, come into close relation with the blood-vessels of the mother. There is not, however, an actual union. Waste-products thus pass from the blood of the embryo into the blood of the mother, which, on the other hand, supplies nutritive material and oxygen. The lack of food-yolk is thus compensated for. (For details of the *embryonic circulation, see p.* 317.)

Several embryos develop in each uterus at the same time, occupying separate swellings. At birth the embryonic membranes are cast off, including the embryonic part of the placenta.

CHAPTER IX.—COMPARATIVE ANIMAL MORPHOLOGY AND PHYSIOLOGY.

The comparison of animals may be conducted on the same principles as the comparison of plants (*p.* 120). *Amœba* and *Vorticella*, both *unicellular* animals, perform all the functions of life, the former being but little differentiated, the latter a great deal. From this point onwards the *multicellular* condition is of great importance, different cells performing different functions, as in plants. Tissues and cellular organs result.

Amœba is usually irregular in **form**, but, when at rest, tends to become spherical. This is simply a physical result of its semifluid nature. The firm cuticle possessed by *Vorticella* necessitates a definite form.

Bilateral symmetry (exhibited by most of the forms) may be conceived of as derived from radial symmetry (seen in *Hydra*), by elongation transverse to the long axis, which, at the same time, shortens. Meanwhile, ventral and dorsal surfaces, and anterior and posterior ends, become differentiated, as the result of a creeping mode of progression. The anterior end ultimately becomes the head, in which some of the most important organs are located.

The higher forms mostly exhibit **segmentation**, that is, a division from before backwards into rings or segments. These, in the *Earthworm*, are similar, but, in the *Crayfish*, are more or less dissimilar, and largely fused. It is thus that distinct body-regions arise. The *Fluke* is unsegmented, and the *Mussel* and *Snail* have lost all traces of segmentation. The last has also become twisted and asymmetrical owing to the development of a spiral shell. In the *Frog*, *Pigeon*, and *Rabbit*, segmentation is much obscured in the adult. It is best seen in the spinal nerves. The jointing of the backbone appears to be a case of "secondary" segmentation—*i.e.*, the segments do not correspond to the primitive ones indicated by the mesoblastic somites (protovertebræ) of the embryo.

Homology and Analogy can be distinguished in animals as well as in plants. Homologous organs agree in relative position and mode of develop-

ment, analogous organs correspond merely in function. For example, the *quadrate* bone of the Pigeon is *homologous* with the *incus* of the Rabbit, though their functions are different, while the breathing-organs of the Snail, Crayfish, and Rabbit are *analogous*, agreeing in function. Homology is, in fact, *morphological*, analogy *physiological* equivalence. It must not be forgotten that organs are often both homologous *and* analogous—*e.g.*, the *eyes* of Frog, Pigeon, and Rabbit.

Serial homology is agreement in plan of structure and mode of development between series of structures—*e.g.*, the segments of the Earthworm, or spinal nerves and vertebræ of the Frog.

1. Protection and Support.—In *Amœba* there is no special modification for this purpose, but in *Vorticella* a firm cuticle is present. Both can form a protective *cyst.* A cuticle is also found in the *Earthworm*, and to a more marked extent in the *Fluke*, where it is much thickened and provided with numerous minute spines. The maximum of cuticular protection is reached in the *Crayfish*, *Mussel*, and *Snail*, where a firm *exoskeleton* is produced by the impregnation of a thickened and laminated cuticle with salts of lime.

In *Hydra* the thread-cells serve as a very effective protection. The *skin* of the *Frog*, *Pigeon*, and *Rabbit* serves for protection, and, in the last two animals, produces *feathers* and *hairs* respectively, for this special purpose. From the *Fluke* upwards, support is largely afforded by what may be termed *indifferent tissues*, *i.e.*, *connective-tissue*, and its modifications, *cartilage* and *bone*. Cartilage first appears in the odontophore of the Snail, and, together with bone, forms in the Frog, Pigeon, and Rabbit a more or less complete *endoskeleton*. The most primitive part of this endoskeleton appears to be the backbone, the foundation of which is the *notochord* of the embryo. In these three highest forms, the body is divisible into an upper, smaller, *neural tube*, contained in the skull and backbone, and a lower larger *visceral tube*, which is bounded by hard parts mainly in the *thoracic* and *pelvic* regions.

2. Nutrition.—The food of *Amœba* can be ingested, and refuse egested at any point of the shapeless body, and the *pseudopodia* are used for overwhelming any minute organisms that may serve as nutriment. *Vorticella* is usually fixed, and the place of pseudopodia is taken by *cilia*, which do not themselves seize food, but cause food-bearing currents to enter the vestibule and gullet. Within the body the food takes a definite course, and the undigested parts are cast out at a special anal area. The necessity for definite points at which food may be taken in, and innutritious residues ejected is brought about by the presence of the firm cuticle.

Hydra presents a great advance upon this state of things. The tentacles can seize small animals (which are first paralyzed by the thread-cells) and convey them to the "mouth." Within the large digestive cavity, they are partly taken in amœba-like by the endoderm cells, and partly reduced to a state of solution by digestive fluids poured out by those cells. The flagella produce currents, which assist in the circulation of food in the cavity, and the rejection of waste by the "mouth." The *Earthworm* is far more highly differentiated in this and other respects. The conversion of radial into bilateral symmetry, in the way already indicated, would cause the "mouth" of a hydra-like animal to be pulled out into a long slit. The closure of this, in the middle of its extent, would lead to the formation of two apertures, one at either end, placing the alimentary canal in communication with the exterior.

The mouth and anus of the Earthworm, &c., can be conceived of as derived in this way from the "mouth" of a form like Hydra. The digestive organs of the Earthworm present a number of special contrivance. The pharynx helps to draw in the food, and the gizzard to crush it, while the lining of the alimentary canal is *glandular* and secretes digestive fluids. There are also, in addition, glandular pouches, the œsophageal glands, attached to the anterior part of the alimentary canal. The typhlosole increases the absorptive surface.

The *Fluke* is a very much modified worm, adapted for a parasitic life, and the digestive organs are much specialized in accordance with this.

The segments of the *Crayfish* bear jointed appendages, which, in the anterior part of the body, are adapted for seizing and crushing food, the reduction of which to a fine state of division is completed by the complex gastric mill. The alimentary canal, like that of the Earthworm, exhibits bilateral symmetry, and its absorptive surface is increased by the ridges present in the intestine. Two very large digestive glands are present, which must be regarded, like all such glands, as extremely complicated pouches or diverticula of the alimentary canal, from which, indeed, they grow out, as the study of development shows.

In the *Mussel*, although the mouth and anus are in the middle line, the alimentary canal is convoluted, as in the higher forms, by which absorptive surface is gained, augmented in this case by a typhlosole. The food is procured by the aid of ciliary currents, and digested by the fluid secreted in the digestive gland surrounding the stomach.

The asymmetry of the *Snail* affects the internal organs, including those of digestion, especially as regards the position of the anus. The odontophore is a very special modification for rasping food, and not only is a hepato-pancreas present, but also salivary glands, the function of which is, however, doubtful.

In the *Frog*, insects are secured as food by means of the tongue, aided by the sticky secretion of numerous small glands. Their escape from the mouth-cavity is prevented by the minute, pointed teeth. The absorptive surface is much increased, not only by the length but by the elevated internal surface of the small intestine. The functions of a hepato-pancreas are here shared between two digestive glands, the liver and the pancreas.

The *Pigeon*, by means of its horny beak, picks up food, which is temporarily stored up in the crop, and acted upon mechanically in the gizzard. Both liver and pancreas are present. The absorptive projections from the lining of the intestine are here, and in the Rabbit, called villi.

The *Rabbit* possesses teeth adapted for cutting and grinding. The flexible, fleshy lips largely aid in seizing food. The alimentary canal is here immensely long, as a result of the vegetable food, and its absorptive surface is, in consequence, extremely large. Not only are liver and pancreas present, but also several pairs of salivary glands, the secretion of which, like that of the latter, converts insoluble starch into soluble diffusible sugar.

Circulation.—In *Amœba* and *Vorticella* this is aided by the presence of a *contractile vacuole*, and in the *Fluke* one of the functions of a circulatory system—*i.e.*, the conveyance of waste-products to organs which get rid of them—is rendered superfluous by the large extent of those (excretory) organs themselves.

The *Earthworm* possesses a well-defined and closed blood system as distinct from a lymph system. The propulsion of blood is effected by the paired hearts. The *Crayfish*, *Mussel*, and *Snail* show no distinction between blood and lymph systems. The blood system in each case is *lacunar*—*i.e.*, the ramifications of the blood-vessels terminate in the lacunæ everywhere permeating the tissues. The heart of the Crayfish possesses no auricles; there are two in the Mussel, but only one (a result of asymmetry) in the Snail. All three hearts are *systemic*, that is to say, they receive oxygenated blood, which they pump to the body at large. In the *Frog*, *Pigeon*, and *Rabbit*, the blood system is closed, owing to the presence of capillaries, which connect the ultimate ramifications of the arteries and veins. The lymph system is, as always, lacunar, but definite trunks are present, best marked in the Rabbit and worst in the Frog. The latter, however, possesses lymph-hearts not seen in the other two forms. The heart in all three is not only systemic but pulmonary, in that it pumps impure blood to the lungs (and in the Frog to the skin also) for purification. Only one ventricle is possessed by the Frog, which involves complicated mechanical contrivances by which the complete mixing of oxygenated and impure blood in the ventricle is prevented. The Pigeon and Rabbit have two completely separated ventricles.

3. **Destructive Metabolism**—(1.) **Respiration.**—This is aided in *Amœba* and *Vorticella*, by the contractile vacuole. In *Hydra*, the *Fluke*, and the *Earthworm*, it is effected by the general surface of the body, beneath which, in the last case, there is a rich supply of blood-vessels. The *Crayfish* and *Mussel* possess gills for breathing the oxygen dissolved in water, while the *Snail*, *Frog*, *Pigeon*, and *Rabbit* possess lungs, by means of which the oxygen in the atmosphere is utilized. The presence of hæmoglobin in the blood of the *Earthworm*, *Frog*, *Pigeon*, and *Rabbit* deserves mention. In the *Crayfish* water is renewed in the gill-chamber mainly by the action of the scaphognathite, and in the Mussel the same end is effected by ciliary action. In the four air-breathing forms inspiration and expiration may be distinguished, and special provisions are made for these—the muscular floor of the Snail's lung—the buccal respiration of the Frog—the contraction and elastic expansion of the body-walls in the Pigeon—and costal, together with diaphragmatic respiration, in the Rabbit. An increase of surface is gained in various ways both in the case of lungs and gills.

(2.) **Excretion.**—The contractile vacuole assists this in *Amœba* and *Vorticella*. The excretory system of the *Fluke* is very complicated, and almost every segment in *Lumbricus* possesses its own pair of nephridia, only two of which are present in the

Mussel, and one (another example of asymmetry) in the *Snail*. The renal function is performed in the *Crayfish* by the paired green glands. The excretory organs of the *Frog*, *Pigeon*, and *Rabbit* are very complicated, but essentially consist of tubules which, in the *Frog*, communicate with the body-cavity by means of nephrostomes. The kidneys of the *Pigeon* and *Rabbit* are not morphologically equivalent to those of the *Frog*, but are preceded in development by transitory Wolffian bodies, which are the exact equivalents of those structures. The kidney of the *Frog* and the Wolffian bodies of the other two forms are at first made up of tubules in which a segmental arrangement can be detected. If the nephridia of the *Earthworm* on either side communicated with a duct which opened near the posterior end of the body, a structure would be produced of similar nature. A urinary bladder is present in the *Frog* and *Rabbit*, which in one case is a rudimentary allantois, and in the other is the proximal end of that structure, and receives the urinary ducts.

4. **Reproduction.**—This is effected **asexually** in *Amœba* and *Vorticella* by means of fission, and in *Hydra* by means of gemmation.

Sexual Reproduction is first hinted at in **conjugation**, which differs somewhat from the same phenomenon as exhibited by plants, in that it is merely a temporary or permanent (as in *Vorticella*) fusion of two similar or dissimilar individuals which leads to more vigorous asexual reproduction.

In *Hydra* both male and female reproductive organs, testes and ovaries, producing male and female reproductive cells (spermatozoa and ova) respectively, are present in the same individual. Fertilization is preceded by the ejection of one or more polar cells from the ovum (*compare ventral canal-cells in the Moss, &c.*), and in most forms at any rate the germinal-cells producing spermatozoa are not entirely used up in the process (*compare the vesicle attached to the spermatozoid of the Fern*).

The testes and ovaries may be termed the *essential* organs, and advance upon the conditions seen in Hydra principally consists in the development of various *accessory* parts, such as ducts, special glands, and copulatory organs. In the *Pigeon* and *Rabbit* the remains of both pro- and meso-nephros become accessory structures of this kind, and in the Frog this is the case with the pronephros, while the meso-nephros ("kidney") performs, in the male, a double function. A cloaca is present in the *Frog* and *Pigeon*, but, in the *Rabbit*, the termination of the alimentary canal is quite distinct from that of the urogenital organs, and opens to the exterior by an anus, while they do so by a urogenital opening.

Considerable variations are presented in **development**, which are largely dependent upon the amount of food-yolk in the egg. In the *Rabbit* this is present in but very small quantity, and the nutritive material and oxygen required by the embryo are supplied by the mother, the embryonic and maternal blood-vessels becoming closely related in the placenta. Waste is carried off in the same manner.

Hydra differs markedly from the higher forms, in that *two* germinal layers only, epiblast and hypoblast, are present. This animal is in fact little more than a permanent gastrula. The embryos of the *Fluke*, *Earthworm*, *Crayfish*, &c., possess *three* germinal layers—epiblast, hypoblast, and mesoblast. Segmentation is well seen in the mesoblastic somites of most of these embryos.

5. Contractility.—This is exhibited in the three forms of movement, amœboid, ciliary, and muscular.

Amœboid movement is typically exemplified in *Amœba*, from which animal its name is derived. It is also observable in the endoderm cells of *Hydra* and the epithelial cells lining the intestine of the *Fluke*. From this animal upwards the power of amœboid movement is mainly retained by the colourless corpuscles found in lymph and blood.

Ciliary movement is first seen in *Vorticella*, and is also shown by the endodermal cells of *Hydra*, and the external surface of the ciliated embryo in the *Fluke*. Cilia are found in the segmental organs and oviducts of the *Earthworm*, and cover the gills, labial palps, and inner side of the mantle-lobes in the *Mussel*, in which animal they play a very important part in respiration and nutrition. In the *Frog* cilia line the mouth-cavity, and are present in the lungs, oviducts, and elsewhere. In the *Pigeon* and *Rabbit* ciliary action is mainly exemplified in the trachea and oviducts. Most spermatozoa are propelled by flagella. This a modification of ciliary movement.

Muscular movement is foreshadowed in the cortical layer of *Vorticella* and tailed cells of the ectoderm in *Hydra*. The muscles are at first largely connected with the skin, as seen in the *Fluke* and *Earthworm.* The exoskeleton of the *Crayfish, Mussel*, and *Snail* serves for the attachment of muscles, as does the endoskeleton of the *Frog, Pigeon*, and *Rabbit.*

Muscular fibres play an important part in nutrition and circulation, entering, as they do, into the walls of the alimentary canal, heart, and vessels. A distinction arises in the highest forms between unstriated and striated muscle, which belong to the internal organs, and the muscles *par excellence* respectively. These are distinguished by histological characters, and their involuntary and voluntary nature, the latter difference depending upon nerve-supply.

6. Irritability and Spontaneity.—(1.) **Nervous System.**—Undifferentiated in *Amœba* and *Vorticella.* The first trace is found in *Hydra.* The *Fluke* possesses a fairly well-developed nervous system with ganglia and nerve cords. The two elements, ganglion-cells and nerve-fibres, are here found, the former being mainly confined to the ganglia. In the *Earthworm* the nervous system is segmentally arranged, but the ganglia, with the exception of the cerebral, are not very distinct, and the ganglion-cells are not confined to them. Nerve-fibres are afferent and efferent, the former being mainly sensory, the latter mainly motor. In the *Crayfish* the ganglia still show segmentation in their arrangement, but are fused anteriorly. At the same time a distinct head, containing the main ganglionic masses and with which the chief sense organs are connected, is present. The nervous system of the *Mussel* is made up of three pairs of ganglia widely separated. Three pairs can also be recognized in the Snail, but here they are very much localized and a distinct head is present. The *Frog, Pigeon*, and *Rabbit* possess very complicated nervous systems, consisting of brain with spinal cord, contained in the neural canal, cranio-spinal nerves, and sympathetic system. The brain becomes more complicated, mainly by the increase in size of the cerebral hemispheres and cerebellum, the former of which are connected together in the *Rabbit* by the corpus callosum and fornix. The sympathetic system present in the *Earthworm* and *Crayfish* in a rudimentary form has to do with the control of the viscera. At the same time, histological distinction may be drawn between medullated and non-medullated nerve-fibres. The latter are especially characteristic of the sympathetic system.

There is reason to believe that the nervous system is derived from the epidermis, with which, in low forms, it often remains closely connected. The deeper position in high forms has been assumed for protective purposes. The development of the brain and spinal cord (*see* Frog) exemplifies the steps in such a change of position.

The typical *form* of the nervous system (when present) in a radially symmetrical animal, is that of a ring. The assumption of bilateral symmetry would pull this out into a long loop, the anterior end of which might thicken into cerebral ganglia. The sides of the loop might remain separate, and even (*comp.* lateral nerves of *Fluke*) become disconnected behind. By the ventral fusion of such lateral nerves a circumœsophageal ring and double ventral cord (*Earthworm* and *Crayfish*) might be produced, or by their dorsal fusion a spinal cord (*Frog*, *Pigeon*, and *Rabbit*) of double nature. The cerebral ganglia of the *Earthworm* and *Crayfish* possibly = the forebrain of the *Frog*, *Pigeon*, and *Rabbit*.

(2.) **Sense Organs.**—These are not present in *Amœba* and *Vorticella*, but are represented in *Hydra* by the trigger-hairs. It may be mentioned here that a sense organ essentially consists of one or more usually elongated *sense-cells*, of epithelial nature, and connected on the one hand with the nervous system, while on the other they are adapted to receive impressions from various stimuli coming, in the large majority of cases, from the exterior.

(*a.*) *Tactile Organs.*—These are represented by the setæ of the *Crayfish*, and by the epithelium covering the labial palps of the *Mussel*, and the tips (?) of the *Snail's* tentacles. Special tactile corpuscles are present in the *Frog*, *Pigeon*, and *Rabbit*. Here, also, the nasal sacs are tactile organs, in so far as they perceive, by means of trigeminal fibres, other than true odours (fragrance and its contrary), and the tongue in so far as it perceives, by means of similar fibres, other than true tastes (sweetness and its contrary).

(*b.*) *Gustatory Organs.*—These are not certainly known except in the *Frog*, *Pigeon*, and *Rabbit*, where, as taste-cells, they are supplied by the glosso-pharyngeal nerve. In the last case they occur aggregated into well-marked taste-buds, localized in the circumvallate papillæ and papillæ foliatæ.

(*c.*) *Olfactory Organs.*—These are probably represented in the *Crayfish* by olfactory setæ, and in the *Snail* by the epithelium on the tips of the tentacles (?), or possibly by the ciliated epithelium lining the pedal gland. The *Frog*, *Pigeon*, and *Rabbit* possess nasal sacs largely lined by olfactory epithelium containing numerous olfactory cells.

(*d.*) *Auditory Organs.*—These are first recognizable in the

Crayfish, where they exist in the form of small, open, auditory sacs, lodged in the basal joints of the antennules, and lined by sensory epithelium. In the *Mussel* and *Snail* closed sacs are found, similar, in essential respects, to the open sacs of the *Crayfish*. By the growth of such simple vesicles into a complicated shape, the membranous labyrinths found in the *Frog*, *Pigeon*, and *Rabbit* are formed during development. To these are superadded the accessory parts making up the middle and external ears.

(*e.*) *Optic Organs.*—Two eyes in the form of pigment-spots are possessed by the ciliated embryo of the *Fluke*. In the *Earthworm* the cerebral ganglia themselves appear to be sensitive to light acting upon them through the translucent skin. The *Crayfish* possesses compound eyes, to which the theory of "mosaic vision" (*p.* 95) is applicable, while the simple eyes of the *Snail* resemble in principle those of the *Frog*, *Pigeon*, and *Rabbit*, which have a double origin, being partly formed by involutions from the exterior, and partly by outgrowths from the fore-brain.

CHAPTER X.—CLASSIFICATION OF ANIMALS.

The following is a brief outline of the classification of animals *comp. p.* 7):—

DIVISION A.—PROTOZOA (*Amœba, Vorticella*).

Unicellular (or if multicellular, as *Collozoum*, the cells are all similar and independent). *Sexual Reproduction* O.

DIVISION B.—METAZOA.

Multicellular; cells interdependent, varying in form and function; *tissues* present. *Sexual Reproduction* present.

A. DIPLOBLASTICA —*Embryo* two-layered.

PHYLUM I. CŒLENTERATA (*Hydra*).—*Symmetry* radial. *Body-wall* of ectoderm and endoderm. *Body-cavity* O. "Mouth" = mouth + anus of Triploblastica.

B. TRIPLOBLASTICA.—*Embryo* three-layered. *Symmetry* (typically), bilateral. *Body-wall* with true mesoderm.

PHYLUM II. VERMES.—*Segmentation* often exhibited (when segments are nearly all similar).

Class 1. Platyelminthes (*Distoma*).—*Segmentation* (in adult), O. *Shape* flattened (usually). *Lateral appendages*, O. True *body-cavity*, O. *Ventral nerve-cord*, O.

Class 2. Chætopoda (*Lumbricus*).—*Segmentation* exhibited. *Shape*, rounded. *Lateral appendages* (when present), not jointed. True *body-cavity* present. *Mouth* ventral. *Ventral nerve-cord* present. *Excretory organs* paired and segmentally arranged.

PHYLUM III. ARTHROPODA (*Astacus*).—*Segmentation* exhibited; *segments* more or less dissimilar; *body-regions* (head, &c.) thus constituted. *Lateral appendages* jointed. *Nervous system* of paired cerebral ganglia, and ventral nerve-cord.

PHYLUM IV. MOLLUSCA. — *Segmentation* (in adult), O. *Mantle* present. *Shell* (usually) present. *Lateral appendages*, O. *Foot* present, as ventral muscular expansion. *Nervous system* more or less concentrated, and mainly formed of ganglionated œsophageal ring.

GROUP 1. LAMELLIBRANCHIATA (*Anodonta, Unio*). —*Head*, O. *Mantle* bilobed. *Shell* bivalve and lateral. *Odontophore*, O. *Nerve-ring* long.

GROUP 2. ODONTOPHORA (*Helix*).—*Head* (usually) distinct, and bearing sense organs. *Mantle*, never bilobed. *Shell* (usually) univalve, and (generally) persists throughout life. *Odontophore* (with two exceptions) present. *Nerve-ring* short.

PHYLUM V. VERTEBRATA. — *Segmentation*, clearest in embryo; *segments*, highly dissimilar. *Limbs*, never more than two pairs, supported by endoskeleton. *Axial endoskeleton*, protecting central nervous system, always present. *Jaws*, almost always present, never modified appendages, move up and down. *Nervous system*, principally formed of brain and spinal cord, enclosed in dorsal neural tube. *Visceral arches* and *clefts*, always present at some time during life.

GROUP 1. ICHTHYOPSIDA.—*Epidermic exoskeleton*, slight or absent. *Notochord*, often persists. *Vertebræ*, when present, without epiphyses. *Brain-case*, always possesses extensive tracts of cartilage. *Occipital condyles*, 0, 1, or 2 (in the last case are ex-occipital, and the basi-occipital region unossified). *Cranial membrane bones*, when present, include a *parasphenoid*. *Blood*, at about same temperature as surrounding medium. *Red-corpuscles*, nucleated. *Heart*, two- or three-chambered. *Aortic arches*, never less than two. *Gills*, always present at some period of life. *Thoracic diaphragm*, O. *Wolffian bodies*, persist. *Mammary glands*, O. *Cerebral Hemispheres*, never united by a corpus callosum. *Hypoglossal nerve*, does not perforate the brain-case. *Sclerotic coat of eye*, when present, cartilaginous or bony. *Amnion*, O. *Allantois*, rudimentary.

Class 1. Pisces (*Fishes*).

Class 2. Amphibia (*Rana*).—*Unpaired fins*, when present, not supported by fin-rays. *Limbs*, when present, on the type of the Sauropsida and Mammalia.

GROUP 2. SAUROPSIDA.—*Epidermic exoskeleton*, as scales or feathers. *Notochord*, never persists. *Vertebræ*, without epiphyses. *Brain-case*, with comparatively little cartilage; *occipital region*, well ossified; *occipital condyle*, 1, partly basi- and partly ex-occipital; *pro-otic*, ossified, never fuses early with other otic bones; no separate *parasphenoid*. *Ankle-joint*, between proximal and distal tarsal bones. *Red blood-corpuscles*, oval and nucleated. *Heart*, three- or four-chambered. *Aortic arches*, seldom more than two. *Gills*, O. *Thoracic diaphragm*, never complete nor functional. *True kidneys*, present, their ducts opening, together with gut and sexual ducts, into a *cloaca*. *Mammary glands*, O. *Cerebral hemispheres*, not united by corpus callosum. *Hypoglossal nerve*, perforates the brain-case. *Sclerotic coat* of *eye*, cartilaginous or bony. *Cochlea*, a straight or slightly coiled tube. *Columella*, well-developed. *Ova*, with much food-yolk.

Segmentation, partial. *Oviparous* or *ovoviviparous* (*i.e.*, eggs hatched internally). *Amnion* and respiratory *allantois*, present.

Class 1. Reptilia (*Reptiles*).

Class 2. Aves (*Columba*).—*Fore-limbs*, modified into (usually) functional wings. *Hind-limbs*, set on very far forwards. *Uropygium*. *Epidermic exoskeleton*, in the form of feathers. *Bones*, light and spongy; *long bones*, in adult, (usually) devoid of marrow. *Cervical vertebræ*, with saddle-shaped articular surfaces. *True sacral vertebræ*, without expanded ribs, and fusing with numerous other vertebræ to form a pseudo-sacrum. *Posterior caudal vertebræ*, (usually) unite together into a ploughshare-bone. *Occipital condyle*, on base of skull. *Parasphenoid*, represented in front by basi-sphenoidal rostrum, behind by basi-temporal plate. *Free carpals*, never more than two; *digits of manus*, never more than three. *Ilia*, extend far in front of acetabulum, which is perforated. *Pubes* and *ischia*, directed backwards, the former rarely, the latter never meeting in a ventral symphysis. *Tarsal bones*, never separate; *digits of pes*, never more than four. *Teeth* (in recent forms), never present. *Blood*, much warmer than surrounding medium. *Heart*, four-chambered: *right auriculo-ventricular valve*, muscular; *ventricular septum*, complete. *Aortic arches*, 1, curving to the right. *Bronchi*, communicate on surface of lung with air-sacs, and these again with the cavities in the bones. *Right ovary* and *oviduct*, rudimentary. *Bursa Fabricii*, present. *Optic lobes*, thrown down to sides of brain.

GROUP 3. MAMMALIA (*Lepus*).—*Epidermic exoskeleton*, in the form of hair, always present at some period of life. *Notochord*, never persists. *Vertebræ*, with epiphyses; *cervical vertebræ*, usually 7. *Occipital region*, well ossified; *occipital condyles*, 2, mostly ex-occipital, but partly basi-occipital. *Otic bones*, early fuse together. *Mandible*, of two pieces only, and articulating directly with squamosal. *Lips*, usually definite and muscular. *Teeth*, when present, only replaceable to a limited extent by new ones. *Large intestine*, very long. *Cloaca*, rarely present. *Blood*, warm (but cooler than in Birds). *Red corpuscles*, round and always non-nucleated. *Heart*, four-chambered; *right auriculo-ventricular valve*, membranous. *Aortic arches*, 1, curving to the left. *Gills*, O. *Epiglottis*, present. *Bronchial tubes*, end in infundibula. *Air-sacs*, O. *Thoracic diaphragm*, complete and functional. *True kidneys*, present, possessing cortex and medulla. *Mammary glands*, present. *Cerebral hemispheres*, with *corpus callosum third commissure* and *corpus mammillare*, present; *optic lobes*, double. *Sclerotic coat of eye*, fibrous. *Auditory ossicles*, 4. *Cochlea*, (almost always) spirally coiled. *Ova*, small. *Segmentation*, (usually) complete and nearly regular. *Viviparous* (usually) and young nourished by milk for some time after birth. *Amnion* and (usually) an *allantoic placenta*, present.

ERRATA.

Page 346, *line* 2, for ilio-pubic, *read* ischio-pubic.

Page 279, paragraph on **Position of Body** should precede account of Skin.

APPENDIX A.—BIBLIOGRAPHY.

The following are the principal works which have been consulted:—

ABBREVIATIONS.

A.B., Annales des Sciences Naturelles (Botanique).
Ar., Archiv für Mikroskopische Anatomie.
E.B., Encyclopædia Brittanica, 9th Edition.
M.J., Morphologisches Jahrbuch.
Pr.R., Proceedings of the Royal Society.
Q., Quarterly Journal of Microscopic Science.
Z., Zeitschrift für Wissenschaftliche Zoologie.

INTRODUCTION.

Balfour—Address to the Brit. Assoc., 1880: *Darwin*—Origin of Species: *Davidson*—Logic of Definition—and Logic of Classification, *Mind*, 1887: *Huxley*—Manual of Invertebrated Animals: *Lankester*—Protozoa, E.B.

PART I.

Allen Grant—The Colours of Flowers: *Arthur, Barnes, and Coulter*—Plant Dissection: *Bentham*—Students' Flora: *Bettany*—First Lessons in Practical Botany: *Bower and Vines*—Practical Botany: *Brefeld*—Botanische Untersuchungen der Schimmelpilze (Penicillium and Zygomyceten): *Darwin*—Climbing Plants, Insectivorous Plants, Fertilization of Orchids: *De Bary*—Comparative Anatomy of Phanerogams and Ferns (English trans.), Comparative Anatomy of Fungi and Mycetozoa (Eng. trans.), Untersuchungen ueber die Familie der Conjugaten: *Eichler*—Blüthendiagramme: *Goebel*—Outlines of Classification and Special Morphology (Eng. trans.): *Gray (Asa)*—Structural Botany: *Hayward*—The Botanist's Pocket-Book: *Hooker*—Students' Flora: *Howes*—Biological Atlas: *Huxley and Martin*—Practical Biology: *Lankester*—Protozoa, E.B.: *Lubbock*—The Fertilization of Flowers by Insects, Flowers, Fruits, and Leaves: *Payer*—Traité d'Organogénie de la Fleur: *Prantl and Vines*—Text-Book of Botany: *Sachs*—Text-Book of Botany (Eng. trans.), Experimental Physiologie: *Shore*—Vegetable Biology: *Strasburger*—Die Angiospermen und die Gymnospermen, Zellbildung und Zelltheilung, Neue Untersuchungen ueber den Befruchtungsvorgang bei den Phanerogamen, &c.: *Strasburger and Hillhouse*—Practical Botany: *Thuret*—Recherches sur la

Fécondation des Fucacées, A.B., 1854: *Van Tieghem et Le Monnier*—Recherches sur les Mucorinées, A.B., 1873: *Vines*—Physiology of Plants.

PART II.

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APPENDIX B.—EXAMINATION QUESTIONS.

N.B.—Those marked L are from the London Calendars. In some cases slight alterations have been made, which are enclosed in brackets.

I. GENERAL QUESTIONS.

1. What is Biology? How is it sub-divided?

2. What do you know of *abiogenesis?*

3. Give a brief sketch of the Evolution Theory.

4. What is meant by the terms Analogy and Homology? Illustrate your answer by examples.

5. Explain, and illustrate by examples, the expression "Alternation of Generations."

6. What is a *type?*

7. What is meant by "struggle for existence," and "survival of the fittest?"

8. What are *cells?*

II. SIMPLE DESCRIPTIVE QUESTIONS.

A. Botanical.

9. Describe the structure, functions, and life-history of the Yeast Plant (*Saccharomyces*). (L., 1877.)

10. Give some account of alcoholic fermentation.

11. Give a general account of the phenomenon of putrefaction. Describe the life-history of the organisms by which it is caused, and the methods which are available for arresting their development. (L., 1879.)

12. Briefly sketch the morphology and physiology of Mucor.

13. Write the life-history of Penicillium. (L., 1884.)

14. Succinctly describe Protococcus.

15. Carefully describe a single cell of Spirogyra, and the changes through which it may pass.

16. Give an account of the reproductive organs and mode of reproduction in Fucus.

17. Write a description of Chara.

18. Describe the structure of the antheridium in Chara.

19. By what different methods can Chara reproduce itself?

20. Write the life-history of a Moss. (L., 1883.)

21. Tabulate the methods of reproduction obtaining in Mosses.

22. Describe in detail the structure of a mature Moss Sporogonium, and trace its course of development from the period of its inception. (L., 1886.)

23. What do you understand by alternation of generation in plants? Illustrate your answer by reference to a Moss and to a Fern. (L., 1887.)

24. Explain from the life-history of a Fern the meaning of "Alternation of Generations." (L., 1882.)

25. Give a general sketch of the life-history of a Fern, from the germination of the spore to the formation of the fertile frond. (L., 1877.)

26. Give a general account of the structure of the rhizome of a Fern (*Pteris*) as seen in transverse section, and a detailed account of the structure of one of the larger fibro-vascular bundles. (L., 1882.)

27. Carefully describe the development of the antheridium, archegonium, and sporophyte in the Fern.

28. Describe the branching of the stem, and the characters and succession of the leaves in *Pinus*. (L.,1886.)

29. Describe in detail the structure of the stem in Pinus after three years growth in thickness. Explain how this growth in thickness takes place. (L., 1885.)

30. Explain the structure of the leaves (including sporophylls) and spores of Pinus.

31. What are the *members* of a plant? State the headings under which they are classified. Is the following statement correct: "*Equivalent members always perform the same or similar*

functions?" Give reasons for your answer.

32. How are leaves classified? How may they vary in form and structure?

33. Enumerate the principal kinds of branching.

35. (*a*) Carefully describe the structure of a typical leaf. (*b*) Describe the minute anatomy of a young dicotyledonous stem, and explain how it afterwards increases in thickness.

35. How are *plant-tissues* primarily divided? Give some account of the modifications found in the most superficial tissue-system.

36. Write a description of the structure and arrangement of the cells composing the meristem at the apex of the primary root of any Angiosperm: specify what plant you have taken as your type. (L., 1886.)

37. Give an account of the distinctive characters of the Epidermis of plants. Describe its development and subsequent mode of growth, and mention the organs which may be developed from it. (L., 1880.)

38. Describe the structure and mode of formation of Cork. (L., 1882.)

39. (*a*) Describe the appearance and structure of a typical stoma. (*b*) What is its position? (*c*) What is its function? (*d*) How does it act? (L., 1887.)

40. Briefly describe the histological elements which enter into the composition of a Fibro-vascular bundle. What is meant by *open*, *closed*, *concentric*, *collateral*, fibro-vascular bundles? Give examples. (L., 1883.)

41. What is Cambium? Describe its mode of formation. (L., 1877.)

42. What is a sieve-tube? What is its structure? What is its position in a Dicotyledon? What is its probable function? (L., 1887.)

43. Describe the organs by which a Bean-plant absorbs water, and give an account of the process of absorption. (L., 1887.)

44. Describe the structure of the stamen of a Phanerogam. What bodies are produced by it, and what happens to them after they are shed? (L., 1882.)

45. What is placentation? Describe its varieties

46. Describe the structure of Pollen-grains, the development of the pollen-tube, and the mode in which the fertilization of the oosphere is effected. (L., 1884.)

47. Describe any typical ovule. In what ways may its structure be modified?

48. How are *fruits* classified? Give examples. What is a *spurious* fruit? Give examples.

49. Describe Cambium. What positions does it occupy in the stem of a typical dicotyledonous plant which exhibits secondary growth in thickness? What are its products in these positions? Describe them. (L., 1884.)

50. State all you know about *chlorophyll* and its uses in the plant economy.

51. State what are the conditions essential to the formation of starch in chlorophyll-corpuscles. Describe the structure of a chlorophyll-corpuscle. (L., 1883.)

52. Give an account of the process of Absorption by Roots. By what means are roots enabled to absorb substances which are insoluble in water? Enumerate the chemical elements contained in the substances absorbed by the roots which are *essential* to the nutrition of green plants. (L., 1884.)

53. Describe in general terms the mode in which the manufacture of albuminoids is effected by the plant. From what sources and in what form do plants obtain their nitrogen. (L., 1880.)

54. How do you account for the formation of Sugar in plants? (L., 1877.)

[See p. 107. Sugar is one of the soluble substances which circulate in the plant. It may also be a reserve material, as in the Sugar Cane and Beet Root. Also formed in fruits, see p. 119.]

55. What functions are performed by the Leaves in Phanerogams. (L., 1877.)

56. Write an account of the functions performed by the epidermal tissue. (L., 1886.)

57. What is meant by Transpiration? Describe simple experiments by which its occurrence and nature may be demonstrated. (L., 1882.)

58. Briefly describe the mode of growth in thickness of the stems and roots of Dicotyledons. State the meaning of the terms Primary Meristem, Secondary Meristem, Procam-

bium, Pericambium, giving illustrative examples. (L., 1884.)

59. Explain briefly the biological significance of (*a*) brightly coloured, and (*b*) irregular flowers, as compared with (*c*) inconspicuous, and (*d*) regular flowers. Give examples. (L., 1886.)

60. Give an account of the phenomena of fertilization in an Angiosperm from the time of application of the pollen-grain to the stigma, up to the moment of impregnation. (L., 1886.)

61. Describe the process of reproduction in a flowering plant, and the minute anatomy of the structures involved. (L., 1879.)

62. Describe the process of impregnation of the ovule in *Phanerogamia* up to the formation of the embryo. (L., 1877.)

63. Describe any provisions for promoting scattering the seed with which you are acquainted. Explain how each operates. (L., 1885.)

64. What provisions are made for the protection of seeds?

65. Describe in detail the development of the sporophyte in *Capsella*.

66. Give an account of the external conditions requisite for germination of a seed and growth of the embryo, and explain how these conditions operate. (L., 1885.)

B. Zoological.

67. Fully describe *Amœba*.

68. How does *Vorticella* (*a*) obtain food, (*b*) digest it, (*c*) get rid of innutritious matter?

69. Give an account of the anatomy of Hydra, and of the methods by which it can reproduce itself. (L., 1880.)

70. Describe, severally, the structure and the functions of the cells which build up a Hydra. (L., 1877.)

71. Describe the development of *Hydra* and *Lumbricus*.

72. Give an account of the structure and life-history of Distoma. (L., 1885.)

73. Give an account of the structure of the vascular and nervous systems in the common Earthworm, and describe in detail its development and life-history. (L., 1883.)

74. Give an account of the structure of the epidermis and its outgrowths in the Earthworm, the Frog, and the Rabbit. (L., 1886.)

75. Give a short account of the mode of life of the Earthworm, more especially of the way in which it obtains and digests its food. (L., 1882.)

76. Describe the digestive, circulating, and excretory organs of an Earthworm. (L., 1882.)

77. Describe the excretory organs of *Lumbricus*, [*Distoma*], *Anodon*, and *Helix*. State, giving reasons for your answer, with which of these forms you consider the Vertebrate excretory organs (kidneys) to be most closely allied. (L., 1883.)

78. Describe the digestive organs of *Astacus*, including the mouth-appendages. (L., 1883.)

79 Give an account of the morphology and physiology of the digestive system of *Astacus*.

80. Describe the *circulatory* and *reproductive* organs of the *Crayfish*.

81. What provision is made for the purification of the blood in *Astacus*, and how is the purified blood distributed to the body?

82. Describe the Nervous System of a [Crayfish], and mention the parts supplied by each ganglion. (L., 1879.)

83. Describe the structure of the Eye and of the Auditory Organ in the Crayfish and in the Snail. (L., 1887.)

84. Give an outline sketch of the reproduction and development of *Astacus*.

85. Make diagrams to illustrate the external characters and digestive organs of Anodon.

86. Describe the circulatory, respiratory, and excretory organs of the Freshwater Mussel. (L., 1879.)

87. Give an account of the sexual organs, and the early development of the Anodon. (L., 1877.)

88. Describe the heart of the Snail and of the Crayfish. (L., 1886.)

89. What is the *odontophore* of the Snail? How does it act?

90. Describe the renal excretory and the reproductive organs of the [Snail], the Earthworm, and the Frog. (L., 1884.)

91. Give an account, with illustrative sketches, of the digestive organs of the common Frog, specifying particularly the different forms of epi-

thelium met with in the several regions thereof. (L., 1883.)

92. Describe the heart of a frog, and the arrangement which causes the head to be supplied with arterial blood, and the impure blood to be sent to the lungs and skin for aeration.

93. Describe the urogenital organs of *Rana*.

94. Describe (*a*) the skull, (*b*) a typical vertebra, (*c*) the sternum, and (*d*) the limb-girdles of *Rana*.

95. Give an account of the structure (including histology), and of the functions of the spinal cord and spinal nerves of the Frog. (L., 1879.)

96. Describe briefly the fundamental properties of the spinal cord in the Frog. By what means would you determine whether a given nerve is motor or sensory? (L., 1882.)

97. Give an outline account of the *brain*, and *sympathetic system* of the *Frog*.

98. Give a description of the minute structure and chemical characters of the following tissues as seen in the Frog:—Cartilage, bone, muscle. From which of the primary cell-layers of the embryo are they respectively developed? (L., 1884.)

99. Describe the changes in the egg-cell which precede fertilization; describe the process of fertilization, and the formation of the primary cell-layers as exhibited in three of the animal types known to you. What is the notochord, and how is it developed in the frog? (L., 1886.)

100. Describe the pre-segmentation changes, mode of impregnation, and early stages of development in the ovum of the frog, as far as the closure of the neural canal. (L., 1883.)

101. Describe the cleavage and the surface appearances of the egg of the Frog and of the Rabbit, up to the time when the first gill-slits appear in the embryo. Give illustrative diagrams of what you describe. (L., 1884.)

102. Give an account of the more important features in the development of the Frog. (L., 1880.)

103. Give a short account, with diagrammatic figures, of the principal changes which occur in the circulatory and respiratory organs during the metamorphosis of the Tadpole into the Frog. (L., 1882.)

104. Carefully describe the metamorphosis of the Frog. What bearing has this on the past history of the group to which it belongs?

105 Describe the skull and limb-girdles of the Pigeon.

106. Give an account of the morphology and physiology of the digestive, respiratory, and urogenital organs in the Pigeon.

107. Make sketches to illustrate (*a*) the brain, and (*b*) the auditory organ of *Lepus*.

108. Describe the histology of the digestive organs in Lepus.

109. Describe the microscopical characters of the circulatory fluids met with in the rabbit, pigeon, frog, astacus, earthworm, and snail. (L., 1886.)

110. Describe the structure of striated muscular fibre. Describe its functions and the various means by which they may be called into activity. (L., 1877.)

111. What is bile, what are its properties, how does it get into contact with the food?

112. What is the importance of the pancreatic secretion in digestion?

113. What changes does the food undergo in the mouth, stomach, and small intestine? State how these changes are brought about

114. What are the functions of the skin? Describe its microscopic structure.

115. Enumerate the *cranial nerves*. From what parts of the brain do they arise? What are their functions and to what parts are they distributed?

116. Describe the structure of the mammalian retina.

117. (*a*) Describe the structure of the ovarian egg of the Rabbit; (*b*) and of the Pigeon; (*c*) and of the Frog; (*d*) from what part of the embryo do they originate? (*e*) what is the structure and origin of the ovarian follicle in the Rabbit, and (*f*) of the ovarian stroma? (*g*) what is the "granulosa" and what the "zona pellucida?" (L., 1887.)

118. Describe the entire life-history (development, minute structure, and reproduction) of any one animal which you have practically studied.

119. Describe the early stages in the development of the egg of the fowl as far as the closure of the neural groove. How do you account for the primitive streak? (L., 1886.)

[The primitive streak appears to represent the blastopore of other forms.]

III. COMPARATIVE QUESTIONS.

In questions of this sort "by far the best method and the most widely available is the use of tables. By this means we are able to work the agreements and the differences to great advantage, and to present them in close contiguity; thereby securing precision to the statement, and also producing on the mind a clear and lasting impression. It is a means also of saving repetition. . . . We take the agreements and the differences and set them over against one another in the form of tabular contrast." (Davidson, *The Logic of Definition*, pp. 304-5.) First deal with the agreements, and then with the differences, using in both cases the headings employed in the body of this work, unless others are indicated. In the differences take a vertical column for each of the things compared. Thus—

I. AGREEMENTS.

1. .—2. .—3. &c., &c.

II. DIFFERENCES.

Headings.	1st Thing.	2nd Thing.	3rd Thing.	
1.				&c.
2.				&c.
3.				&c.
&c.	&c.	&c.		

A. Botanical.

120. Give a full account of the differences which exist between an Alga and a Fungus with regard to the mode of their nutrition. (L., 1880.)

121. Describe the structure and position of the sexual reproductive organs in Mucor, Chara (or Nitella), and a Flowering-plant. (L., 1884.)

122. Describe the female sexual organ in a *Moss*, *Chara*, and *Penicillium*. (L., 1886.)

123. Describe the sexual reproductive organs of a Fern and of a Flowering-plant, and state how fertilization is effected in the two cases. (L., 1883.)

124. State the difference between Tubers and Tuberous Roots, giving examples. (L., 1877.)

125. Give an account of the morphology of the following fruits:—Apple, Strawberry, Orange, Fig. (L., 1888.)

B. Zoological.

126. Compare and contrast *Amœba* and *Vorticella*.

127. Contrast the Vascular and Alimentary Systems in *Lumbricus* and *Distoma*. (L., 1882.)

128. Compare the nervous systems of *Lumbricus* and *Astacus*.

129. Compare the excretory organs of an Earthworm with those of a Mussel and a Crayfish, pointing out the resemblances and differences in each case. (L., 1882.)

130. Compare the alimentary canal and appended glands in *Rana* with the corresponding structures in *Lepus*.

131. Point out the corresponding regions in the Brain of an [Amphibian] and a Mammal, and state what are the relations of the three primary Brain-vesicles to these regions. (L., 1880.)

132. Describe the organs of circulation (heart and main arteries and veins) and respiration in the Frog in its mature and immature states. (L., 1886.)

133. Trace the history of the post-oral gill-slits and their accompanying cartilaginous bars and vascular arches in the Frog, Fowl, and Rabbit. (L., 1885.)

134. What temporary organs are developed in the embryo Frog which are absent from the embryo Bird and Mammal, and what in the two latter which are absent from the former? (L., 1879.)

135. Compare the skull of the Rabbit and the Frog, especially in regard to the attachment of the jaw-apparatus to the cranium and other points which distinctly characterize the higher as contrasted with the lower vertebrata. (L., 1884.)

136. Compare with one another the breathing organs and the mechanism of respiration in a frog and in a rabbit. Give figures showing the condition of the heart and great arteries in these animals, and indicate in each case the nature of the blood in the several cavities of the heart. (L., 1883.)

C. Mixed.

137. What are the differences between Plants and Animals? What

are the reasons for regarding Protococcus (= Chlamydococcus, Hæmatococcus) as an animal? (L., 1887.)

138. How does the nutrition of an animal differ from that of a plant, in respect of (1) The substances assimilated, (2) The mode in which they are assimilated? (L., 1879.)

139. How does the chemical nature of the food required respectively by animals, green plants, and colourless plants differ? (L., 1886.)

140. Describe the structure and life-history of *Amœba*, and compare its mode of nutrition and chemical activity with that of Protococcus and of the yeast-plant. (L., 1877.)

141. Trace the process of Histological Differentiation in the following series of organisms:—(*a*) *Protococcus, Chara, Fern;* (*b*) *Amœba, Vorticella, Hydra, Mussel.* (L., 1883.)

142. Trace the progress of (*a*) Morphological Differentiation, (*b*) the Division of Physiological Labour, in the following series of the organisms:—(1) *Protococcus, Chara, Bean;* (2) *Amœba, Hydra, Crayfish.* (L., 1882.)

146. Illustrate, with diagrams, from the structure of typical organisms, the principle of Repetition of similar parts. (L., 1879.)

IV. QUESTIONS REQUIRING DESCRIPTION AND COMPARISON.

A. Botanical.

147. Give a full account of the life-history of the Yeast-fungus (*Saccharomyces*). What conclusions can be drawn from the facts of its nutrition which are applicable to that of the higher plants? (L., 1882.)

148. Describe the *Yeast Plant,* with reference to its structure and functions. How does it differ from *Protococcus?*

149. Describe the thallus of Mucor (*a*) when grown on an aerial substratum; (*b*) when grown submerged in a saccharine nutritive fluid. (*c*) What functional differences does the thallus exhibit under those conditions? Describe (*d*) the normal process of vegetative multiplication in Mucor; (*e*) the sexual organs and process of sexual reproduction. (*f*) What is the most important structural difference between Mucor and Spirogyra? (L., 1887.)

150. Give an account of the structure and life-history of Mucor, and point out the structural differences which exist between this plant and Penicillium. (L., 1884.)

151. Describe and contrast the development of the asexual spores of *Penicillium* and *Mucor.* (L., 1880.)

152. Describe the sexual reproduction of *Chara.* Compare it with the corresponding process in *Mucor,* and any *Moss.*

153. "Conjugation is the simplest form of a sexual process among plants." Discuss this statement, and compare the process of conjugation in Mucor with the process of fertilization in Chara. (L., 1880.)

154. Write an account of the life-history of Fucus. Compare its mode of fertilization with that found in Spirogyra. (L., 1885.)

155. Describe (*a*) the general form of the oophyte (oophore generation) in a Fern; (*b*) the parts by which it is nourished, and how they operate; (*c*) the sexual organs, and the process of fertilization; (*d*) compare a Fern in respect of these features with a Gymnosperm. (L., 1887.)

156. Describe the general structure of the frond of a Fern, and state in what respects it differs from the leaf of a flowering-plant. (L., 1880.)

157. Describe the structure of the mature ovule of a Gymnosperm, and point out the differences between it and the mature ovule of an Angiosperm. (L., 1883.)

158. Give an account of the process of fertilization in a flowering-plant, and compare it with the process of fertilization in *Chara.* (L., 1883.)

159. Describe the structure of the stamen and of a pollen-grain a Flowering-Plant. What structures in a Fern correspond to these? (L., 1882.)

160. (*a*) What is a vascular bundle? (*b*) Describe the elements composing it. (*c*) How does a vascular bundle originate? (*d*) What is the function of the several parts of a vascular bundle? How does a vascular differ from a fibro-vascular bundle? (L., 1887.)

161. Give the essential characters

of *roots*, explaining how they grow in length, and originate lateral branches. What are their functions? Compare them with those of the *leaf.*

B. Zoology.

162. Describe the structure and life-history of Vorticella. In what respects does Vorticella resemble Amœba, and in what does it differ from it? (L., 1880.)

163. (*a*) Describe the general form of Vorticella; (*b*) the different external and internal organs which it possesses, and their supposed functions; (*c*) its mode of reproduction; (*d*) any other features of importance connected with its life-history. (*e*) What is the most important difference between Vorticella and Hydra? (L., 1887.)

164. Give an account, with diagrams, of a transverse section of a Hydra and of an Earthworm. Describe carefully the cell-layers and the cavities present in each case, and contrast them with one another. (L., 1886.)

165. Describe the reproductive processes and the development of the egg in Hydra, and contrast therewith the modes of reproduction observed in [Vorticella] and Amœba. (L., 1884.)

166. Give a brief account of the physiology of Respiration. Describe fully the means by which respiration is effected in the following animals—Earthworm, Snail, Crayfish, Frog. (L., 1880.)

167. What is the nature of the Renal excretion? Describe the structure and exact position of the excretory organs in the Earthworm, Snail, Crayfish, and Frog. (L., 1884.)

168. Describe the Vascular systems of the Mussel, Snail, and Crayfish, and indicate the points wherein they differ in structure and function. (L., 1883.)

169. Describe and compare the structure of the Renal organs in a [Snail], a Swan Mussel, and a Frog. (L., 1880.)

170. Describe the organs of Respiration and Circulation in the common Snail, and contrast them, in structure and function, with those of *Anodon.* (L., 1883.)

171. Describe, with illustrative figures, the Heart and great vessels of the Frog, and contrast them with the corresponding parts of the Rabbit. (L., 1884.)

172. Describe with figures the Brain of a Frog, and compare it with that of a Rabbit. What do you know concerning the functions of the several parts of the brain in the Frog? (L., 1882.)

173. (*a*) What are the protovertebræ? (*b*) How does the notochord originate in the Frog? (*c*) How are the vertebræ laid down in the tadpole? (*d*) Describe the vertebral column of the adult Frog. (*e*) In what important respects do the centra of the vertebræ of the Frog, the Bird, and the Rabbit differ from one another? (L., 1887.)

174. Give an account of the structure of the Genito-Urinary organs of the Fowl. Compare these organs of the Fowl with those of the Frog and of the Rabbit. Distinguish in each case the conditions of the two sexes, and describe briefly the microscopic structure and development of the ova and of the spermatozoa. (L., 1887.)

175. Carefully describe the *brain*, *cloaca*, and *skeleton* (including the *hip-girdle*) *of the hind limb* in *Columba.* Compare the cloaca with that of *Rana*, the brain with that of *Lepus.*

176. What is a "dental formula?" Give an example. Write an account of the gross and minute structure of a Rabbit's (or other Mammal's) incisor. Describe the jaws and hard palate of any *Mammal*, and compare them with the corresponding region in a typical Bird.

V. QUESTIONS ON TECHNICALITIES.

A. Botanical.

177. What is the botanical definition of a Fruit? Distinguish between *true* and *spurious* fruits. (L., 1883.)

178. Explain succinctly the following botanical terms, giving examples: —*Cork-cambium*, *node*, *closed bundle*, *medullary ray*, *stoma*, *secondary xylem*, *hard bast*, *microspore*, *macrospore*, *cyme*, *raceme*, *pseudocarp*, *follicle.*

B. Zoological.

179. Explain the following terms by reference to *Astacus:*—*Segmentation* *epimeron*, *sternum*, *tergum*, *pleuron*,

scaphognathite, *protopodite*, *exopodite*, *endopodite*, *branchiostegite*, *mid-gut*.

180. Explain fully the terms, *mesoblastic somites*, *medullary groove*, *amnion*, *allantois*, *yolk-sac*, and *placenta*.

181. Explain the following terms by reference to *Lepus*:—*Hind-brain*, *pineal gland*, *Cowper's glands*, *rami communicantes*, *Fallopian tube*, *axis*, *atlas*, *retina*, *membranous labyrinth*.

VI. QUESTIONS INVOLVING A KNOWLEDGE OF CLASSIFICATION.

The essential, fundamental, or most important differences between forms, are embodied in the definitions of the groups to which they belong.

A. Botanical.

182. Point out the most important differences between (*a*) *Mucor*, *Spirogyra*, *Fucus*, (*b*) *Funaria*, *Pteris*, *Pinus*, and *Angiosperms*.

B. Zoological.

183. How do Protozoa differ from higher animals (Metazoa) as regards (*a*) structure, (*b*) reproduction? Compare the process of fission in *Amœba* with the segmentation of the ovum in [*Rana*]; pointing out the resemblances and differences between the two cases. (L., 1883.)

184. In what essential respects does the structure of Hydra differ from that of Vorticella? Describe the methods of reproduction in each of these animals. (L., 1884.)

185. Give an account of the structure of Hydra, and of Vorticella. What is the fundamental difference between the two? (L., 1886.)

186. (*a*) Describe from without inwards the structures visible in a transverse section of a Hydra; (*b*) describe similarly a transverse section of an Earthworm taken about the fortieth segment. In both cases describe the tissues present and the characters of the cells which form them. (*c*) State what is the most important structural difference between Hydra and the Earthworm as shown by these two sections. (L., 1887.)

187. Describe and roughly sketch a transverse section of the body of a Hydra and of an Earthworm. Point out in order of their importance the differences between the two animals as shown in the sections. (L., 1887.)

188. How do the *Protozoa* differ, on the one hand from plants, and on the other from higher animals? Describe carefully a member of the group, and give its life-history.

189. Point out the corresponding structures in a Snail and a Pond-mussel which lead to their association in the group Mollusca. Describe and contrast the digestive, nervous, and circulatory systems of the two animals. (L., 1884.)

190. Mention the chief points of difference between vertebrates and invertebrates.

191. Describe the manner in which the mandibular arch is connected with the skull in amphibians, birds, and mammals.

192. Describe and illustrate, by means of sketches, the chief points of difference between the skeleton of the Rabbit as a typical mammal, and that of the common Fowl as a typical bird. (L., 1885.)

INDEX-GLOSSARY TO INTRODUCTION AND PART I.

A

Abiogenesis (ἀ-, not; βίος, life; γένεσις, birth). *See* Spontaneous Generation.

Absorption (*absorbeo*, I suck up)—Taking in food by diffusion, 12, 106, 123.

Accretion (*ad*, to; *cresco*, *cretum*, grow)—Growth by addition of layers to the outside, 2.

Achene (ἀ-, not; χαίνω, I gape, open)—A dry indehiscent, one-seeded fruit, 115, 116.

Acropetal succession (ἄκρον, a point; πέταλον, a leaf)—Development of lateral members on an axis, so that any member is nearer the apex than the next member, 20.

Acuminate (*acumen*, a sharp point)—Gradually tapering to a point, 89.

Acute—Pointed, 89.

Adnate (*ad*, to; *nascor*, *natum*, be born)—United to, 87.

Adventitious (*adventitius*, foreign, strange, unusual)—Not produced in regular order, 92.

Aestivation (*æstas*, summer)—Arrangement of flower-leaves in the bud, 97.

Air-bladders, 30.

Air-space—A gas-containing space arising in a tissue by the separation, rupture, or absorption of cells, 43, 49, 56, 91.

Alcohol, 12.

Alder, 85.

Aleurone grains (ἄλευρον, fine flour or grain)—Minute, variously-shaped masses of proteid reserve-materials occurring in seeds, 120.

Alkaloids, 108.

Alternation of generations—The succession of asexual and sexual stages in the life-history of the same form, 125; Table, 126, 128; Mucor, 19; Penicillium, 22; Chara and Nitella, 41; Moss, 42; Fern, 50; Pinus, 64; Angiosperm, 76.

Ammonia, 108.

Ammonium tartrate, 5, 12.

Amœba (ἀμείβω, I change)—4, 5.

Amorphous (ἀ-, not; μορφή, a form)—Without regular external form, 2.

Amplexicaul (*amplector*, *amplexus*, embrace; *caulis*, the stalk of a plant)—Clasping the base of the stem, 87.

Analogy—Physiological equivalence, 50.

Anatomy—Fern, 52, 56; Pinus, 65, 71, 74; Angiosperm, 78, 90, 92, 102.

Anatropous. *See* Inverted.

Andrœcium (ἀνὴρ, a man; οἶκος, a house)—The male sporophylls taken collectively, 99, 101, 103.

Anemophilous (ἄνεμος, the wind; φίλος, loving)—Wind-pollinated, 109.

Angiosperm (ἀγγεῖον, a vessel; σπέρμα, a seed), 76, 122, 123, 124, 127, 128.

Angular—Three or more sided in cross-section, 78.

Animals—Distinguishing characters, 4; Excretion, 108; Fertilization by, 109; Dispersion of seeds by, 119; Muscle and nerve of, 127.

Annual—Living one year, 76.

Anterior—The side of a lateral structure which is turned away from the axis bearing it, 103.

Anther (ἀνθηρὸς, flowery; ἄνθος, a blossom)—The dilated end of a male sporophyll in which the pollen sacs are imbedded, 73, 99, 102.

Antheridium (ἀνθηρὸς, flowery, -ιδιον, a diminutive suffix)—The male organ of Cryptogams, 128; Penicillium, 22, 124; Fucus, 33, 124; Chara and Nitella, 38, 125; Moss, 46, 48, 125; Fern, 59, 62, 64, 125; Pinus, 74; Angiosperm, 105.

Apex, 30, 35.

Apical cells—Cells by which apical growth is effected; Fucus, 32; Chara and Nitella, 36; Moss, 44, 49; Fern, 53, 56, 59; Pinus, 65, 66; Angiosperm, 79.

Apical growth—Increase at the apex by the division of one or more apical cells; Penicillium, 20.

Apocarpous (ἀπὸ, from, apart; καρπὸς, fruit)—With the carpels distinct, 100.

Apogamy (ἀπὸ, negative; γάμος, marriage)—The non-sexual production of the sporophyte from the oophyte, 62.

Apospory (ἀπὸ, negative; σπορὰ, seed)—The vegetative production of the oophyte from the sporophyte, 62.

Appendages of fruit, 119.

Apple, 116.

Aralia, 95.

Archegonium (ἀρχὴ, beginning; γονὴ, birth, production)—The flask-shaped female organ typically developed in Mosses and Ferns, 128; Moss, 46, 48, 49, 125; Fern, 60, 62, 125; Selaginella, 64; Pinus, 74, 75, 125; Angiosperm (?), 105, 125.

Archesporium (ἀρχὴ, beginning; σπορὰ, seed)—The cell or cells from which spore-mother-cells are immediately derived, 59, 74, 102.

Archicarp (ἀρχὴ, beginning; καρπὸς, fruit). *See* Carpogonium, 22.

Aril (*arillus*, a wrapper)—An outgrowth from a seed-coat or funicle, 115.

Arum, 94, 95, 97.

Ascidians—A group of animals possessing a firm cellulose investment, 5.

Ascospore (ἀσκός, a wine-skin; σπορά, seed)—A spore developed within an ascus, 23.

Ascus (ἀσκός, a wine-skin)—A sac-like fungal cell within which spores are formed.

Asexual generation (ἀ-, not; *sexus*, sex). *See* Sporophyte.

Asparagus, 79.

Asplenium, 62.

Assimilation (*assimilo*, I make like to)—The building up of food into protoplasm, 12.

Axil (*axilla* = *ala*, the arm-pit)—The upper angle formed by the attachment of a lateral member, 35.

B

Bacillus (*bacillus*, *bacillum*, a little staff), 14; B. Subtilis, 15.

Bacteria, 14-16, 123, 124, 128.

Bacterium (βακτήριον, a little staff), 14.

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Bark—The external parts of a Dicotyledonous stem, deadened by the development of successive layers of cork-cambium, placed deeper and deeper, 65, 70, 78, 83, 108.

Base, 30, 35.

Bast. *See* Phloem.

Basifixed—With connective and filament in the same line, 99.

Bast-fibres. *See* Phloem-fibres.

Bean, 117.

Beech, 86.

Bees, 109.

Beetroot, 92.

Belladonna, 88.

Bent—An ovule with flexed nucellus, 101, 103, 115.

Berry—A succulent, indehiscent fruit, with pulpy meso- and endo-carp, 118.

Biennial (*biennis*)—Lasting or living for two years, 76.

Bifacial (*bi-*, two; *facies*, a face)—A flat leaf with its upper and lower sides structurally different, 86, 91.

Binomial nomenclature (*bi-*, two; *nom-en*, a name), 8.

Biogenesis (βίος, life; γένεσις, birth)—The production of life from life, 3.

Biology (βίος, life; λόγος, speech, discourse), 1; Subdivisions, 3.

Bipinnate (*bi-*, two; *pinna*, a feather)—A compound leaf, composed of pairs of leaflets arranged on secondary axes, 88.

Birds'-foot trefoil, 98.
Bisexual (*bi-*, two; *sexus*, sex)—Possessing both male and female sporophylls, 46, 96, 108.
Blackberry, 118.
Blade—The expanded part of a leaf, 86.
"Bleeding"—The oozing of sap from cut stems, &c., 107.
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Botany (βοτάνη, a plant), 3.
Bough, 77.
Bracken. *See* Fern.
Bract (*bractea*, a thin plate of metal)—A scale-leaf in the axil of which a flower-branch is developed, 84, 94.
Bracteole (*bracteola*, dim. of *bractea*)—A small scale-leaf upon a flower-branch of the highest order, 96.
Branch—A lateral axis, 77.
,, Fertile, 33; With naked base, 40; Proembryonic, 40.
Branching—Dichotomous, 30; Forked branching. *See* Inflorescence.
Broom, 109, 119.
Bryophytes (βρύον, a moss; φυτὸν, a plant), 128.
Bud, 108; Limited growth, 71; Of trees, 84; Terminal, 35; Underground, 48; Unlimited growth, 65, 71.
Budding—Vegetative reproduction by buds, 11, 13, 121, 124.
Bulb—A leaf-bud with thickened leaves containing reserve-materials, 84, 108.
Bulbil. *See* Starch-star, 40.
Bundle—An aggregation of conducting and supporting elements which are mostly elongated.
,, —Bicollateral (*bi-*, two; *con*, together; *latus*, *lateris*, the side)—As collateral, but with an additional Phloem-mass internal to the Xylem, 81.
,, —Cauline (*caulis*, the stalk of a plant)—In the stem only, 84.
,, —Closed—Devoid of cambium, 79.
,, —Collateral—With Xylem and Phloem on the same radius, the former internal, 56, 66, 80; Common, commencing in a leaf and passing down into the stem, 65, 79.
,, —Concentric, with the Xylem enclosed by the Phloem, 55.
,, —Fibro-vascular, in Monocotyledons—a bundle + the investing sclerenchyma of the ground tissue, 80.
,, —Open—Possessing cambium, 66, 80—Radial, with the Xylem and Phloem arranged alternately, 57.
,, —Vascular. *See* Vascular bundle.

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C

Cactus, 77, 90.
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Calcium phosphate, 12.
Calyptra (*καλύπτρα*, a covering)—The ruptured end of a moss-archegonium, carried up by the developing capsule, 42, 49.
Calyptrogen (*καλύπτρα*, a covering; *γεννάω*, I produce)—A layer of meristem, from which the root-cap is derived, 92.
Calyx (*κάλυξ*, a case or cup)—The outer whorl of the perianth in a typical flower, 97.
Cambium (*cambio*, I exchange). *See* Meristem, secondary.
,, —Cork—Cambium, from which cork-cells originate, 66, 69, 72, 81.
,, —Fascicular and Interfascicular—Cambium of the vascular ring developed in and between the primary bundles respectively. *See* also Pericambium, 66, 70, 72, 81, 123.
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Capsella, 113.
Capsule (dim. from *capsa*, a chest or case)—(1) The upper part of a moss-sporogonium—(2) The spore-containing part of a fern-sporangium—(3) A dry dehiscent fruit, composed of more than one carpel.
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Carpogonium (*καρπὸς*, fruit; *γονή*, birth, production)—A female organ which does not contain a distinct oosphere, but is stimulated to further growth by fertilization, 22.
Carraway, 116.
Caryopsis (*κάρυον*, a nut; *ὄψις*, appearance)—A dry indehiscent fruit, with pericarp and seed-coat firmly united, 116.
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Central, in the Fern, the cell which after pinching off the ventral canal-cell becomes the oosphere, 61; Egg (*see* oosphere)—Embryo, in Angiosperms, the cell which originates most of the embryo sporophyte, 114; Female, 124; Glandular, a cell which has to do with secretion or excretion, 92; Guard, one of two cells bounding a stoma, 56, 71, 91, 107; Initial (*see* apical cells), 66, 71, 92; Internodal, in Chara and Nitella, an elongated cell extending from one node to the next, 37; Lid, in the Moss, one of four cells terminating the neck of the archegonium, 47, 60, 62; Male, 124; Neck-canal, a single cell, or one of a series of cells, occupying the axis of the neck of an archegonium, 49, 60, 61; Nodal, in Chara, a cell which by repeated division produces a node, 37; Polar (*see* ventral canal), 49, 125; Pollen-mother, a cell which divides up into pollen-grains, 74, 102; Reproductive, 74, 105; Secretory (*see* glandular), 84; Segmental, a cell cut or segmented off from an apical cell, 37, 44, 53, 56; Spore-mother, a cell which divides into spores, 43, 59; Stalk (1) in Chara, the cell by which the carpogonium is attached (2) in the Fern, the cell from which the sporangium-stalk develops, 39, 59; Terminal, in Chara, the cell forming the leaf-apex, 37; Vegetative, a cell performing other than a reproductive function, 74, 105; Ventral canal, in forms with archegonia, a cell at the bottom of the neck, which is pinched off from the oosphere-mother-cell, 47, 60, 61, 125; Wall, in the Fern, one of four cells split off the capsule-cell to form the sporangium-wall, 59.

Cell-fusion—A tissue-element formed by the fusion of two or more cells, 54.

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Centric—A leaf without structural differentiation of surfaces (*see* bifacial), 92.

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Channelled—Marked by longitudinal grooves, 78.

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Cholera, 14.

Choripetalous (χωρὶς, apart; πέταλον, a leaf)—With free petals, 98.

Chorisepalous (χωρὶς, apart; *sepalum*, a leaf)—With free sepals, 97.

Chromatophore (χρῶμα, colouring matter; φορὸς, bearing; φέρω, I bear)—A colour-containing corpuscle, 24.

Circulation—Movement of fluids through the plant-body, 107, 123.

Clasping Organ. *See* Tendril, 77.

Classification, 7, 127.

Claw—The stalk of a petal, 98.

Cleaver, 77.

Cleistogamous (κλειστὸς, closed; γάμος, marriage)—Producing small self-fertilized flowers, in addition to the ordinary ones, 110.

Climber, Hook, 77; Root, 77.

Climbing, 77; Plants, 111, 127.

Cocoa-nut, 114.

Collar—The remains of the sporangial wall, surrounding the base of the columella in Mucor, 18.

Collenchyma (κόλλα, glue; ἔγχυμα, something poured or filled in)—Parenchyma in which the adjacent angles of the cells are thickened and capable of swelling up, 83.

Colour of flowers, 109, 125; Of fruits, 119.

Columbine, 117.

Columella (dim. from *columna*, a column)—The strongly-curved septum (with contained protoplasm) which bulges into the sporangium of Mucor, 17, 43.

Comparison, 4.

Compound—A leaf in which the lamina is subdivided into leaflets, 87, 88.

Conceptacle (*conceptaculum*, a receptacle)—A pit lined by epidermis, in which the sexual organs of Fucus are contained, 33.

Conditions—General, of plant life, 111.

Conduplicate (*con*, together; *duplico*, I double). *See* Vernation, 84.

Cone—The female flower of Pinus, 73.

Conjugation (*con*, together; *jungo*, *jug-*, join)—The fusion of two similar gametes, Mucor, 19, 124; Spirogyra, 29, 124.

Connate—The fusion of two opposite sessile leaves so as to enclose the stem, 87.

Connective—The continuation of the filament between the anther-lobes, 99.

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Cordate (*cor*, *cordis*, the heart)—Heart-shaped, with the base attached, 90.

Cork—Layers of rectangular cells with thickened suberized walls, and no protoplasm, 65, 70, 78, 81.

Corm, (κορμὸς, the trunk of a tree)—The thickened base of a stem, containing reserve-materials, 77, 108.

Corolla (*corolla*, dim. of *corona*)—The inner whorl of the perianth in a typical flower, 97, 98, 103.

Corona (*corona*, a crown, a wreath)—The ligules of a flower's petals taken collectively, 98.

Cortex (*cortex*, bark)—The ground-tissue of a stem or root, which is external to the bundles, 37, 65, 72, 81, 123.

Cotton, 115.

Cotyledons (κοτυληδὼν, a cavity, such as the socket of the thigh-bone)—The simple first leaves of a seedling, 63, 75, 84, 90, 114, 120.

Crataegus, 108.

Creeping, 77.

Crenate (*crena*, a notch)—A leaf-margin with small rounded indentations, 89.

Crocus, 77.

Cross-fertilization—Impregnation of the female gamete of one flower by the male gamete of another, 40, 125.

Crown-cells—The pointed cells, collectively constituting the crown, which cap the oogonium in Chara and Nitella, 39.

Cryptogams (κρυπτὸς, hidden; γάμος, marriage), 128; Vascular, 128.

Crystalline, 2.

Cucumber, 81, 118.

Cushion—The thickened central part of a Fern-prothallus, on which the archegonia are borne, 59.

Cuspidate—Suddenly tapering to a point, 89.

Cuticle (*cuticula*, dim. from *cutis*, the skin), 66, 71, 79, 90.

Cutin, 43.

Cyclic (κυκλικὸς, circular)—Flowers in which the component leaves are arranged in whorls, 97.

Cylindrical, 90.

Cyme (κῦμα, a young sprout of a cabbage, literally anything swollen)—An inflorescence in which the branches of any order outgrow the axis on which they are developed, 96.

Cymose. *See* Cyme, 95.

Cystolith (κύστις, a bag or bladder; λίθος, a stone)—An ingrowth of cell-wall impregnated and incrusted with $CaCO_3$.

D

Dahlia, 92.

Daisy, 77, 95, 100, 109.

Dandelion, 77, 100, 116, 119.

Darwin, 6.

Date, 114, 118.

Deadnettle, 98, 100, 109.

Decurrent (*de*, down; *curro*, I run)—A sessile leaf with wings running down the stem, 87.

Decussate (*decussis*, the Roman numeral X, hence used of the intersection of two lines in the form of a cross; *decusso*, I divide crosswise)—Opposite leaves in which the alternate pairs are arranged at right angles. (Name given from appearance in plan), 85.

Definition, 7.

Dehiscence (*de*, apart; *hisco*, I gape)—The opening of an anther or fruit by slits, pores, or valves, 73, 100, 102.

Dermatogen (δέρμα, the skin; γεννάω, I produce)—Meristem-layer originating the epidermis, 65, 72, 79, 92, 114.

Descent, 6.

Destructive Metabolism (μεταβολὴ, change)—The breaking down of complex substances into simple ones, 123.

„ —Yeast, 13; Bacteria, 15; Mucor, 18; Penicillium, 22; Protococcus, 26; Spirogyra, 28; Fucus, 34; Chara and Nitella, 40; Moss, 47; Fern, Pinus, and Angiosperm, 108.

Development—The sum of the stages passed through by an organism before becoming adult, 3.

„ —Mucor, 19, 20; Penicillium, 22; Spirogyra, 30; Fucus, 34; Chara and Nitella, 41; Moss, 49; Fern, 62; Pinus, 75; Angiosperm, 102, 112; Monocotyledon, 14; Dicotyledon, 113.

Diadelphous (δὶς, doubly; ἀδελφὸς, a brother)—With the stamens united by their filaments into two groups, 99.

Dicotyledons, 65, 76, 78, 81, 83, 84, 92, 97, 113, 122.

Didynamous (δὶς, doubly; δύναμις, power)—An andrœcium composed of two long and two short stamens, 100.

Differentiation, 120.

Digestive cavity, 4.

Diœcious (δὶς, doubly; οἰκία, a house)—(1) In Fucus and the Moss, with the male and female organs on different plants; (2) in Phanerogams, with male and female flowers on different plants, 33, 46, 97.

Distribution, 3.

Divergence, 85.

Division of lamina, 87; Of labour, 106, 120.

Dodder, 106, 123.

Dorsifixed (*dorsum*, the back)—With the filament attached to the back of the anther, 99.

Drupe (δρύππα, *drupa*, an over-ripe olive)—A succulent indehiscent fruit, with hardened endocarp, 118.
Dust, 25, 106.

E

Edibility of fruit, 119.
Egg-apparatus—Oosphere + synergidae, 105, 125.
Egg-cell. *See* Oosphere.
Electricity, 112.
Elliptical, 89.
Elm, 86.
Embryo, Pinus, 75; Angiosperm, 114.
Embryo-sac—The macrospore of Phanerogams, 74, 75, 105, 108, 112, 114.
Embryology, 3.
Emulsion, 183.
Endocarp (ἔνδον, within; καρπὸς, fruit)—The innermost layer of the pericarp, 116, 118.
Endodermis (ἔνδον, within; δέρμα, the skin). *See* Bundle-sheath.
Endogenous (ἔνδον, within; γεννάω, I produce)—The origin of lateral roots from the deeper tissues, 57.
Endogonidium (ἔνδον, within; gonidium)—A gonidium developed within a special receptacle, 13, 17, 19, 122, 124.
Endosperm (ἔνδον, within; σπέρμα, seed)—Tissue, serving in Phanerogams, for the nourishment of the developing sporophyte, 74, 75, 105, 106, 112, 114, 120, 128.
Endospore (ἔνδον, within; σπορά, seed)—The inner layer of the spore-coat, 19, 44, 63, 74.
Energy, potential and kinetic, 5, 13.
Entire—An unindented leaf-margin, 88.
Entomophilous (ἔντομα, insects; φίλος, loving)—Insect-pollinated, 109.
Epibasal—The half of an embryo, which originates the ascending axis, 63.
Epicarp (ἐπὶ, upon; καρπὸς, fruit)—The outermost layer of the pericarp, 116, 118.
Epidermis (ἐπὶ, upon; δέρμα, skin)—The (usually single) external layer of cells in higher plants, 31, 43, 128; Fern, 52, 53, 56, 57, 123; Pinus, 65, 66, 71, 72, 123; Angiosperm, 78, 79, 90, 91, 106, 123.
Epigean (ἐπὶ, upon; γῆ, the earth)—Germination, in which the cotyledons are carried above ground and become green, 120.
Epigynous (ἐπὶ, upon; γυνὴ, a woman)—A flower in which the hollow torus partly walls in the ovary, 101, 103.
Epipetalous (ἐπὶ, upon; πέταλον, a leaf)—Situated on a petal, 103.

Epiphyte (ἐπὶ, upon; *φυτὸν*, a plant)—A plant which grows upon another plant, but does not derive nutriment from it, 92.

Equatorial plate—A disc which forms the centre of the spindle-form often assumed by a dividing nucleus, 28.

Erect, 77.

Etiolated (*étioler*, to grow slender)—In *green plants*, containing etiolin, instead of chlorophyll, owing to deprivation of light, 111.

Etiolin—A yellow colouring-matter, closely allied to chlorophyll, 112.

Eucyclic (εὖ, well; *κύκλος*, a circle)—A flower with alternating whorls, each whorl containing the same number of parts, 104.

Evergreen, 85.

Evolution, 5, 6.

Excretion, 124; Yeast, 13; Angiosperm, 108.

Exospore (ἔξω, without; *σπορά*, a seed)—The outer layer of the spore-coat, 19, 44, 49, 63, 74.

Extine (*ex*, outside)—The exospore of the pollen-grain, 74, 102, 105.

Extrose (*extrosus* = *extra*, without, and *verto*, I turn)—An anther which dehisces externally, 100.

F

Fats, 1, 5, 83.

Female organs, 125, 128; Penicillium, 22, 124; Fucus, 33, 124; Chara and Nitella, 39, 125; Moss, 46, 125; Fern, 60, 125; Pinus, 74, 125; Angiosperm, 125.

Fermentation—The splitting-up of compounds by the influence of organized or unorganized bodies known as ferments, which do not themselves enter into the reactions, 11, 12, 13, 18, 107, 123.

Fern, 4, 50, 83, 106, 107, 108, 111, 122, 123, 124, 127, 128.

Fertilization—Fusion of well-differentiated male and female gametes, 124, 125, 128; Penicillium, 22; Fucus, 34; Moss, 48; Fern, 62; Selaginella, 64; Pinus, 75; Angiosperm, 110.

Fibrous, 92.

Ficus, 83.

Fiddle-shaped, 90.

Fig, 115.

Filament—The stalk of a stamen, 39, 73, 99, 102.

Fir. *See* Pinus.

Fishes, 6.

Fission (*findo*, *fissum*, split)—Vegetative reproduction by splitting into two or more equal parts, 26, 121, 124.

Fistular (*fistula*, a tube, pipe)—Hollow, 78.

Flagellum (*flagellum*, a whip, a lash)—An elongated motile thread of protoplasm, 14, 24, 60, 121, 127.

Flesh colour, 109.

Flies, 109.

Floral diagram—A diagrammatic plan of a flower, 104.

Flower—A shoot modified for spore-bearing, or "an axis bearing sporophylls" (Goebel).

,, —Pinus, 72, 124; Angiosperm, 93, 108, 124.

,, —Arrangement, 94; Female, 73, 96, 115; Male, 72, 96, 115; Relative position of parts, 101, 103.

Flowering Plant, typical. *See* Angiosperm.

Flower-stalk, 115.

Foliar gap, in the Fern—A mesh in the vascular network, opposite the origin of a leaf-stalk, 52.

Follicle (*folliculus*, a little bag)—A dry, many-seeded fruit composed of one carpel dehiscing along the ventral suture, 117.

Food—Matter taken in from the exterior to compensate for waste, or aid in growth, 2, 5, 12, 123.

Foot, 63, 75.

Forget-me-not, 96.

Form of leaf, 86.

Foxglove, 117.

Fragmentation, in Chara—The breaking up of the nucleus in old internodal cells, 38.

Frog, 6.

Fruit—A structure formed by the growth of parts surrounding the sexual organs, as a result of fertilization; Penicillium, 23; Angiosperm, 112, 115.

,, —Dehiscent (capsular)—A fruit which splits open to liberate the seed, 117, 118; Dry, a fruit with dry pericarp, 116; Indehiscent, a fruit which does not split open to liberate the seeds, 116, 118; Spurious, in Angiosperm, a fruit formed by the growth of parts external to the ovary (*e.g.*, torus), 112; Succulent, a fruit with more or less juicy pericarp, 118; True, in Angiosperms, a fruit formed by the growth of the wall of the ovary only. *See* Pericarp, 115.

Fucus (*φῦκος*, *fucus*, sea-weed), 30, 50, 122, 123, 124, 125, 127.

Funaria (*funarius*, adjective from *funis*, a rope or cord). *See* Moss.

Fungi, 5, 128.

Funicle (*funiculus*, dim. of *funis*, a rope)—The stalk of the ovule, 101, 102, 103, 115.

G

Galium, 77.

Gamete (γαμέω, I marry)—A sexual cell: two similar or dissimilar gametes fuse to produce a sexual spore or zygote, 18.

Gamopetalous (γάμος, a marriage; πέταλον, a leaf)—With petals more or less united, 98.

Gamosepalous (γάμος, a marriage; *sepalum*, a leaf)—With sepals more or less united, 98.

Gemma (*gemma*, a bud) in the Moss—A small aggregate of vegetative cells, subserving vegetative reproduction, 48.

Gemmation. *See* Budding.

Genera, 7.

Genetic spiral—A spiral line drawn round a stem and cutting the insertions of successive leaves, 85, 86.

Geological record, 6.

Geotropism (γῆ, the earth; τροπή, a turning)—Certain phenomena exhibited by growing organs owing to the action of gravity, 112.

Geranium, 116, 119.

Germination (*germinatio*, a shooting forth, a budding)—The development of reproductive bodies—*e.g.*, spores and seeds. It is often preceded by a dormant period. Pinus, 75; Angiosperm, 120.

Germ-tube, in the Moss—A chlorophyll-bearing tube, which grows out of the germinating spore, 49.

Gills, 6.

Glabrous (*glaber*, without hair, smooth)—Hairless, 93.

Gland—A collection of glandular cells, concerned with secretion or excretion—Water, 92. *See also* Nectary.

Gonidiophore (*gonidium*; φορός, carrying; φέρω, I carry)—In Fungi, hyphae bearing gonidia, 17, 21, 112.

Gonidium (γόνος, offspring; -ιδιον, diminutive suffix)—An asexual spore, 124.

Gooseberry, 118.

Gorse, 90, 98, 99, 100, 109.

Grant, Allen, 106.

Grass, 78, 85, 87, 90, 91, 97, 100, 113, 120.

Gravity, 112.

Growing point—A collection of actively dividing cells, forming the top of many growing members; Fern, 51, 52; Pinus, 65, 71; Angiosperm, 79, 92, 114.

Growth—"Permanent change of form accompanied usually by increase in bulk"; (Vines), 2, 13.

Gymnosperm (γυμνός, naked; σπέρμα, a seed), 64, 128.

Gynandrous (γυνὴ, a woman; ἀνὴρ, ἀνδρὸς, a man)—A stamen situated on the gynœcium, 103.

Gynœcium (γυνὴ, a woman; οἰκία, a house)—The female sporophylls taken collectively. The term pistil (*pistillum*, a pestle) is often applied to simple and syncarpous gynœcia, and to each separate carpel in an apocarpous gynœcium.

H

Hæckel, 5.

Hæmatococcus. *See* Protococcus.

Hairs—More or less elongated trichomes, 31, 33, 92, 110, 111, 114, 119, 127; Glandular-secreting or excreting hairs, 93.

Handle, in Chara—An elongated cell projecting inwards from each antheridial shield, 39.

Hart's-tongue Fern, 58.

Hay-Bacillus, 15.

Hazel, 96, 97, 115, 116, 118.

Head—A racemose inflorescence, with shortened axis, bearing a group of sessile flowers, 95.

Head-cell, in Chara—One of a group of cells borne by the handle, 39.

Heat-stiffening—3.

Heliotropism (ἥλιος, the sun; τροπὴ, a turning)—Certain phenomena exhibited by growing organs owing to the action of light, 112.

Hemisphere, 63.

Henbane, 118.

Herb—A plant with no, or but little, woody tissue, 76.

Herbaceous—Not woody, 77, 85.

Heredity, 6.

Hesperidium—A modified berry, with pulp formed by outgrowth of the endocarp, 118.

Heterocarpic (ἕτερος, another; καρπὸς, fruit)—Producing more than one kind of fruit, 119.

Heterostyly (ἕτερος, different; style)—The possession of styles (and stamens) of different lengths by different individuals, 110.

Hibiscus, 118.

Hip, 115.

Hilum (*hilum*, a very small thing)—In the seed: the point where the funicle is attached, 115.

Hippuris, 81.

Hirsute, 93.

Histology (ἱστὸς, a thing woven; λόγος, speech, discourse)—The morphology of minute structure, 3; Fucus, 31; Chara and Nitella, 36; Moss, 44; Fern, 52, 56; Pinus, 65, 71, 74; Angiosperm, 79, 91, 92, 93, 102.

Holly, 91.

Homology (ὁμὸς, like, equal; λόγος, relation)—Morphological equivalence, 50.

Honey-guide—Any structure in the flower which indicates the position of the nectar, 109.

Horse-chestnut, 88.

Hydra, green, 5.

Hydrogen, 12.

Hypericum, 99.

Hypha (ὑφὴ, a thing woven)—One of numerous filaments making up the plant body in most Fungi, 16, 20, 121, 123.

Hypobasal—That half of an embryo which originates the descending axis, 63.

Hypocotyl—That part of the embryo-stem which is below the insertion of the cotyledons, 77, 120.

Hypogean (ὑπὸ, beneath; γῆ, the earth)—Germination in which the cotyledons remain underground, 120.

Hypogynous (ὑπὸ, beneath; γυνὴ, a woman)—A flower with conical or flat torus, in which the gynœcium is higher, or at least not lower than the other parts, 101, 103.

Hypophysis (ὑπὸ, beneath; ἀπόφυσις, a projecting part), in Angiosperms—The suspensor cell which is nearest and helps to form the embryo.

I

Imbricate (*imbricatus*, overlapping like gutter-tiles). *See* Vernation, 84.

Indiarubber, 83; Plant, 83, 91.

Indusium (*indusium*, a garment), in the Fern—An outgrowth covering a group of sporangia, 57.

Inedibility of fruit, 119.

Inferior—An ovary which is partly walled-in by the torus, 101, 103.

Inflorescence (*infloresco*, I begin to blossom)—A branch-system bearing flowers, 72, 94.

Innovation, in the Moss—The dying down of old parts, by which branch-ends become separate plants, 47.

Insectivorous plants, 5, 107.

Insects, 102, 122, 123, 125; Night, 109.

Integument—The covering of an ovule, 74, 113.

Intercellular space—A space formed between cells, as a result of more or less rounding-off of these, 83, 108, 123.

Internode (*inter*, between; node)—A part of an axis between the insertion of lateral members, 36; Suppression, non-development, 77.

Intine (*in*, within)—The endospore of the pollen-grain, 74, 102.

Introrse (*introrsus*, inwards)—An anther which dehisces internally, 100.

Intussusception (*intus*, inside; *suscipio*, *susceptum*, take up)—The intercalation of new molecules between pre-existing ones, 2.

Inverted (= anatropous,—ἀνατρέπω, I turn back)—An ovule with straight nucellus, which is sharply flexed on the funicle, 101, 103, 115.

Involucre (*involucrum*, a wrapper)—A collection of bracts surrounding a head, 95.

Iris, 86, 103.

Iron, 24.

Irregular—A calyx, corolla, or flower, which not more than one plane can divide into corresponding halves, 98, 104, 109.

Irritability—Liability to be affected by external agents, 127; Protococcus, 26; Fucus, 34; Chara and Nitella, 41; Moss, 49; Fern, 62; Angiosperm, 111.

Isotagmata (ἴσος, equal; τάγμα, something arranged)—The physical units which have been supposed by some to make up protoplasm, 1.

Ivy, 77, 84, 92, 95.

K

Keel—The two cohering anterior petals of a papilionaceous corolla (*e.g.*, Furze), 98.

L

Labiate (*labium*, a lip)—A calyx, corolla, or flower, which possesses a lipped form, 98, 99.

Lady-fern. *See* Fern.

Lamina (*lamina*, a plate of metal, &c.)—The expanded part of a leaf, 86, 91, 98.

Lanceolate (dim. of *lancea*, a lance)—Shaped like a lance-head, and attached by the base, 90.

Land plant, 106.

Lateral—On the side, 103.

Lateral line, in the Bracken Fern—A pale streak running along either side of the rhizome, and indicating the absence of external sclerenchyma, 54, 108.

Latex (*latex*, a liquid). *See* Milk, 83.

Lavender, 93.

Leaf—(For definition, *see p.* 35)—35, 123, 127, 128; Moss, 44, 45; Fern, 55; Pinus, 71; Angiosperm, 84, 106, 108.

Leaf; Scale, 71, 84; Foliage, 71, 84, 125; Flower, 84, 97, 102, 125; Arrangement, 84; Edge, 88; Apex, 89; Outline, 89; Perianth, 97.

Leaflet—One of the subdivisions of a compound leaf, 36, 87, 88.

Leaf-stalk, 55, 56, 86.

Leaf-trace—That part of a common vascular bundle (*which see*) situated in the stem, 65.

Leaf-wall, in the Moss—A longitudinal septum by which a segmental cell is divided into outer and inner halves, 44.

Legume (*legumen*, a bean)—A dry dehiscent fruit composed of one carpel splitting along the ventral suture, and also opposite it.

Lemon, 118.

Length of stems, 77.

Lenticel (*lenticula*, a small lentil, or anything shaped like it)—A porous area in a cork layer, by which communication between the exterior and the internal tissue is kept up, 81.

Lid, in the Moss—That part of the capsule which falls off, 42.

Life-history—The cycle of changes passed through by an organism, 2.

Light, 111, 127, 128.

Lignin (*lignum*, wood)—A mixture of substances found in cell-walls (especially of the Xylem) which have become woody, 54.

Ligule (*ligula*, a little tongue)—An outgrowth from the upper side of a leaf at the junction of lamina and petiole or sheath, 87, 98.

Lily, 104.

Limb—The stalk of a petal, 98.

Lime, 70; Oxalate, 17, 122; Carbonate, 91, 122.

Linear, 90; Series, 7.

Linseed, 115.

Lipped. *See* Labiate, 98, 99.

Liverwort, 128.

Living matter, 1.

Lobed, 88, 90.

Local death, 2.

Locomotion, 4, 127.

Loculicidal (*loculus*, a little place, a compartment; *cædo*, I cut)—A capsule which splits midway between the dissepiments, 117.

Lubbock, 90.

Lyrate—Shaped like a lyre, 90.

M

Mace—The aril of the Nutmeg, 115.

Macrosporangium (μακρὸς, large; σπορά, seed; ἀγγεῖον, a vessel)—A sporangium producing macrospores, 128; Selaginella, 64; Pinus, 74; Angiosperm, 100.

Macrospore (μακρὸς, large; σπορά, seed)—A large asexual spore, from which a female prothallus originates; Selaginella, 64; Pinus, 74; Angiosperm, 108, 124.

Magnesium, 12; Sulphate, 12.

Male fern. *See* Fern.

Male organ, 125; Penicillium, 22, 124; Fucus, 33, 124; Chara and Nitella, 38, 125; Moss, 46, 125; Fern, 59, 125; Pinus, 74, 125; Angiosperm, 105, 125.

Malic acid, 62.

May, 168.

Medulla (*medulla*, the marrow of bones), in Fucus—The looser internal tissue, 31, 122.

Mericarp (μέρος, a part; καρπὸς, fruit)—One of the separating parts of a split-fruit, 116.

Meristem (μεριστὸς, divided)—A tissue made up of actively dividing cells, from which permanent tissues originate. It is—(1) *Primary*, entirely making up embryos, very young organs, and growing points; (2) *Secondary*, occurring in layers among permanent tissue. *See* Cambium, 52, 56.

Mesocarp (μέσος, middle; καρπὸς, fruit)—The middle layer of the pericarp, 116, 118.

Mesophyll (μέσος, middle; φύλλον, a leaf)—The ground tissue of the leaf, 56, 71, 91, 106, 123.

Micellæ (dim. of *mica*, a grain). *See* Isotagmata, 1.

Micrococcus (μικρὸς, little; κόκκος, a berry), 14.

Micropyle (μικρὸς, little; πύλη, a gate), in the ovule—The point where the nucellus is left uncovered, 74, 75, 110, 114, 115.

Microsomata (μικρὸς, little; σῶμα, σώματος, a body)—Minute granules found in, and probably forming part of protoplasm—Cell-walls are built up from them, 28.

Microsporangium (μικρὸς, little; σπορὰ, seed; ἀγγεῖον, a vessel)—A sporangium producing microspores, 102, 108, 124; Selaginella, 64, 73; Angiosperm, 100, 102.

Microspore (μικρὸς, little; σπορὰ, seed)—A small asexual spore from which a male prothallus originates; Selaginella, 64; Pinus, 74, 124; Angiosperm, 100, 102, 108, 124.

Midrib, 30, 45.

Milk—A solution of proteids, carbohydrates, &c., in which minute particles of fat and resin are mechanically suspended, 83.

Milk-cell (tube)—An elongated branched cell containing milk, 83.

Moisture, 3, 111, 120.

Monadelphous (μόνος, alone; ἀδελφὸς, a brother)—With the stamens united by their filaments into one group, 99.

Monocotyledons, 76, 78, 83, 84, 87, 92, 97, 114.

Monoecious (*μόνος*, single; *οἰκία*, a house)—(1) in Fucus and the Moss—With the male and female organs on the same plant; (2) In Phanerogams—With male and female flowers on the same plant, 38, 97.

Monopodial—With a main axis, 50.

Monosymmetrical—Divisible by one plane only into corresponding halves, 104.

Morphology (*μορφή*, a shape; *λόγος*, speech, discourse), 3; comparative, 120; Yeast, 11, 12; Bacteria, 14; Mucor, 16, 18; Penicillium, 20; Protococcus, 23; Spirogyra, 27; Fucus, 30; Chara and Nitella, 34; Moss, 42; Fern, 50; Pinus, 64; Angiosperm, 76.

Moss, 42, 50, 62, 85, 122, 123, 127, 128.

Moss-fruit. *See* Sporogonium, 42.

Motile stage (Protococcus), 24.

Mouse-ear Chickweed, 96.

Movement, of water, 107; Of gases, 108; Streaming, 111.

Mucilage, 115.

Mucor (*mucor*, mould), 16, 20, 112, 122, 124, 128.

Mucor-yeast, 18.

Mucronate (*mucro*, *mucronis*, a sharp point)—Tipped with a hard point, 89.

Mulberry, 115.

Muscle-fibres, 127.

Mycelium (*μύκης*, a mushroom; λί, cloth)—The plant-body of a fungus, 16, 20.

N

Neck—The free canal-containing end of an archegonium, 46, 60, 74, 75.

Nectar—The sugary fluid secreted by a nectary, 102, 109, 125.

Nectary—A collection of nectar-secreting cells, 102.

Nephrodium. *See* Fern.

Nerve, 127.

Neutral lines, in Chara—The motionless streaks where opposing currents of protoplasm in the cell adjoin, 41.

Nicotine, 108.

Nitella, 34, 122.

Nitrogen, 12.

Node (*nodus*, a knot)—The parts of an axis which bear lateral appendages, 35—Basal, 36.

Non-living matter, 1.

Notched, 89.

Nucellus, in the ovule—The internal tissue, within which the embryo-sac is situated, 74, 101, 103, 105, 112.

Nucleus—A more solid particle formed within most cells, 12; Generative, 105; Secondary, 105; Polar, 105.

Nut—A dry, indehiscent, one-seeded fruit, with sclerenchymatous pericarp, 115, 116.

Nutmeg, 115.

Nutrition—The function of taking in food to compensate for waste, or effect growth, and building it up into more complex compounds, 125; Yeast, 12, 13; Bacteria, 15; Mucor, 18; Penicillium, 22; Protococcus, 24; Green plants, colourless plants and animals, 25; Spirogyra, 28; Fucus, 34; Chara and Nitella, 40; Moss, 47; Fern, Pinus, and Angiosperm, 106.

O

Oak, 88.

Obcordate (*ob*, in opposition; cordate)—Shaped like a heart, and attached by the apex, 90.

Oblanceolate (*ob*, in opposition; lanceolate)—Shaped like a lance-head, 90.

Oblong, 89.

Obovate (*ob*, in opposition; ovate), 90.

Obtuse—Blunt-ended, 89.

Octant, 63.

Odour, 110, 125.

Oil, 120—Ethereal, 93.

Onion, 84, 90.

Oogonium (ᾠὸν, an egg; γονὴ, production)—A rounded female organ, containing one or more oospheres, which do not develop within it—Fucus, 33.

Oophyte (ᾠὸν, an egg; φυτὸν, a plant)—The sexual generation, 1; Table, 126, 128; Mucor, 20; Penicillium, 22; Chara and Nitella, 41; Moss, 44, 47, 49; Fern, 59, 62, 63; Pinus, 64, 74, 75; Angiosperm, 104, 108, 112.

Oosphere (ᾠὸν, an egg; σφαῖρα, a globe)—A rounded, passive female gamete, without cell-wall, 125; Fucus, 33; Chara and Nitella, 39; Moss, 47; Fern, 60, 61, 62; Pinus, 74; Angiosperm, 105, 111.

Oospore (ᾠὸν, an egg; σπορὰ, seed)—The sexual spore produced by the fertilization of the oosphere; Fucus, 34; Chara and Nitella, 40, 41; Moss, 49; Fern, 62; Pinus, 75; Angiosperm, 114.

Operculum (*operculum*, a lid, a cover). *See* Lid, 42.

Opposite, 85, 104.

Orange, 118.

Orbicular (*orbiculus*, dim. of *orbis*, a circle)—Circular, or nearly so, 89.

Orchid, 98, 100, 103, 110.

Organic substance, 25, 107.

Orthostichy (ὀρθὸς, straight; στίχος, a row)—A vertical rank of lateral appendages, 85.

Orthotropous. *See* Straight.

Oval, 89.

Ovary, in Angiosperms—The lower part of the gynœcium, in which the ovules are enclosed, 101, 112, 115, 116, 128.

Ovule—The macrosporangium of Phanerogams, 74, 75, 101, 102, 110, 128.

Ovum. *See* Oosphere.

Oxidation, 2, 13.

Oxygen, 12, 13, 108, 120, 124, 127, 128.

P

Palmate (*palma*, the palm of the hand)—(1) Leaf-venation, in which several strong bundles enter the lamina together, and diverge—(2) A compound leaf composed of leaflets attached in a group, 87, 88.

Palmatifid, partite, sect—A simple leaf, lobed respectively, moderately, deeply, and very deeply, in a palmate manner, 88.

Panicle (*panicula*, a tuft)—A compound raceme, 95.

Papilionaceous (*papilio*, a butterfly)—Butterfly-shaped, 98, 99.

Papilla, apical, in Chara—The receptive apex of the oosphere, 39.

Pappus (πάππος, *pappus*, used with modern meaning)—A circlet of hairs representing the calyx in some fruits, and assisting in dispersion by the wind, 119.

Parallel, 87.

Paraphysis (παρά, beside; φύω, I grow), in the Moss—One of numerous thread or plate-like hairs, found growing among the sexual organs, 46, 47.

Parasite—An organism living in, or upon, another organism, and deriving nourishment from it, 92, 106, 123.

Parenchyma (παρέγχυμα, the spongy substance of the lungs)—Tissue composed of cells, which are fairly equal in their different dimensions, 43; Phloem,—Parenchyma occurring in the Phloem, 55, 69, 80; Xylem,—Parenchyma occurring in the Xylem, 55, 80; Conjunctive, in the Fern—Parenchyma contained within the vascular bundles, 55; Palisade, in bifacial leaves—The upper part of the mesophyll, composed of one or more layers of elongated cells closely packed together at right angles to the surface, 91; Spongy, in bifacial leaves—The lower part of the mesophyll, composed of irregular cells, and containing numerous air-spaces, 91.

Parsnip, 103.

Pasteur's solution, 12.

Pea, 117.

Peduncle (*pedunculus*, used with modern meaning)—The stalk of a flower, 96.

Peltate (πέλτη, a shield)—With the leaf-stalk attached to the under side, 87.

Penicillium (*penicillum*, a painter's brush), 20, 122, 123, 124, 128.

Penicillium-yeast, 22.

Pennywort, 87, 88.

Perennial (*perennis*, lasting)—Living more than two years, 70.

Perfoliate (*per*, through; *folium*, a leaf)—A sessile leaf, with lobes that are fused to the stem, and one another, 87.

Perianth (περὶ, around; ἄνθος, a flower), in the flower—Those floral leaves which are external to the sporophylls, 97, 101, 102, 103, 115.

Periblem (περίβλημα, anything thrown round)—Meristem layers originating the cortex, 65, 71, 79, 92, 114.

Pericambium (περὶ, around; cambium), in the root—A layer, or layers of meristem, situated within the endodermis, 72, 79, 123.

Pericarp (περὶ, round; καρπὸς, fruit), in the fruit—The metamorphosed wall of the ovary, 116.

Perichaetium (περὶ, round; χαίτη, hair), in the Moss—The collection of foliage-leaves surrounding a group of archegonia, 46.

Periderm (περὶ, around; δέρμα, the skin)—A cork layer + the cork cambium, 81.

Perigonium (περὶ, around; γονὴ, birth, production), in the Moss—The collection of modified foliage-leaves surrounding a group of antheridia, 46.

Perigynous (περὶ, around; γυνὴ, a woman)—A flower with cup-shaped torus, on the margin of which the androecium and perianth are inserted, 101, 103.

Perisperm (περὶ, around; σπέρμα, a seed)—A term applied to the nucellus when it persists in the seed, and contains reserve materials, 112, 120.

Peristome (περὶ, around; στόμα, a mouth), in the Moss—A collection of slender processes partly closing the mouth of the ripe capsule, 42.

Petal (πέταλον, a leaf)—One of the leaves of the corolla, 97, 102.

Petaloid (πέταλον, a leaf; εἶδος, form)—Petal-like, 107.

Petiole (*petiolus*, a little foot, a stalk)—Leaf-stalk, 86, 91.

Phanerogams (φανερὸς, evident; γάμος, a marriage), 128.

Phelloderm (φελλὸς, cork; δέρμα, the skin)—Chlorophyll-containing layers of cells, sometimes originating from cork-cambium, on the inside, 81.

Phloem (φλοιὸς, the inner bark)—The part of a vascular bundle which contains sieve-tubes; Fern, 54, 56, 57; Pinus, 66, 69; Angiosperm, 80, 91, 92.

Phloem, primary—Situated within the primary bundles of the unthickened stem, 66; secondary—formed by the cambium-ring of a thickening stem or root, 66, 81.

Phloem-fibres, 54, 80.

Phloem-sheath, in the Fern—A sheath of parenchyma within the bundle-sheath, 53, 55.

Phosphorus, 5, 12.

Phycophaein (φῦκος, *fucus*, sea-weed; φαιὸς, dusky), in Fucus—A brown pigment, 32.

Phyllode (φύλλον, a leaf; εἶδος, form)—A leaf-like stem, 78.

Phyllotaxis (φύλλον, a leaf; τάξις, arrangement)—Arrangement of mature leaves, 84.

Physiology (φύσις, nature; λόγος, speech, discourse), 3; Comparative, 120; Yeast, 12-14; Mucor, 18, 19; Penicillium, 22; Protococcus, 24; Spirogyra, 28; Fucus, 34; Chara and Nitella, 40; Moss, 47; Fern, 62; Pinus, 75; Angiosperm, 106.

Pink, 98.

Pinna (*pinna*, a feather)—One of the leaflets of a pinnate leaf, 55.

Pinnate—(1), Leaf-venation with a central midrib, from which branches run out in a feather-like way; (2), a compound leaf composed of leaflets arranged along a central axis, 55, 87, 88.

Pinnatifid, partite, sect—A simple leaf, lobed respectively moderately, deeply, and very deeply in a pinnate manner, 56, 88.

Pinnule—A sub-division of a pinna, 56.

Pinus, 64, 78, 79, 81, 83, 92, 102, 104, 111, 123, 124, 128.

Pistil. *See* Gynœcium.

Pit—An unthickened area in a thickened cell-wall, 54; Bordered, with opening narrower than the floor. By transparency the two form together a sort of double border, 69; Scalariform, narrow transverse pits arranged serially like the rungs of a ladder, 80.

Pit-membrane—Part of the original thin wall which floors the pit, 54, 69.

Pitcher-plant, 4, 5, 90, 107, 123.

Pith—Ground-tissue situated within a ring of vascular bundles, 52, 65, 81.

Placenta (*placenta*, a flat cake)—That part upon which ovules are borne, 59, 101, 102, 103.

Placentation—Arrangement of ovules, 101, 103; Axile, in a compound two-or-more-chambered ovary, attached to placentas situated one on the inner side of each loculus, 101; Marginal, in a simple ovary, borne on united (and usually thickened) margins of the carpel, 101, 102; Parietal, in a compound one-chambered ovary, attached to the side-walls, 101.

Plane, lateral—A vertical plane, perpendicular to the median one, and separating anterior and posterior halves, 103; Oblique, one of the two vertical planes passing through the junction between the two preceding, and making an angle of 45° with them, 103; Median (antero-posterior) in a leaf or flower, a vertical plane passing through the axis and separating right and left halves, 86, 103.

Plants, colourless, 24, 106, 123; Distinguishing characters, 4; Green, 24, 111, 123, 124; Multicellular, 121; Unicellular, 120.

Plastic materials—Compounds formed from the food, and used in building up the plant body, 107.

Plastic products. *See* Plastic material, 25.

Plerome (πλήρωμα, something that fills up)—A core of meristem originating the vascular bundles and pith, 65, 71, 79, 92, 114.

Plicate (*plico, plicatum*, fold), 84. *See* Vernation.

Plum, 118.

Plumule (*plumula*, dim. of *pluma*, a downy feather)—Rudimentary shoot of the embryo, 75, 77, 114, 120.

Pollen (*pollen*, fine flour). *See* Pollen-grain, 73, 100, 109, 110.

Pollen-grain—The microspore of Phanerogams, 74, 75, 100, 102, 108, 110.

Pollen-sac—The microsporangium of Phanerogams, 73, 74, 100, 102.

Pollen-tube—The fertilizing tube which grows out of the pollen-grain, 74, 75, 105, 110, 125, 128.

Pollination—Application of pollen to the micropyle (in Pinus) or the stigma (in Angiosperms)—Bird, 110; Cross, 108; Insect, 109; Self, 108, 110; Snail, 110; Water, 110; Wind, 75, 109.

Pollinium—All the pollen-grains in a pollen-sac agglutinated together, 100, 110.

Polyadelphous—With the stamens united by their filaments into more than two groups, 99.

Polypody (Polypodium), 58.

Polysymmetrical—Divisible by more than one plane into corresponding halves, 104.

Polytrichum (πολὺς, many; θρὶξ, τριχὸς, a hair). *See* Moss.

Pore-capsule—A capsule which dehisces by pores, 117.

Porous. *See* Pore-capsule.

Posterior—The side of a lateral structure, which is turned towards the axis bearing it, 103.

Potassium, 12.

Potassium Phosphate, 12.

Potato, 77, 83, 112.

Praefloration (*prae*, before; *flos, floris*, a flower)—Arrangement of flower-leaves in the bud, 97.

Praefoliation (*prae*, before; *folium*, a leaf)—Arrangement of foliage-leaves in the bud, 55, 84.

Prickle—A sharp protective outgrowth of epidermis and the underlying cortex, 123.

Primordial Utricle (*primordialis*, original; *utriculus*, a little bag)—Layer of protoplasm lining a cell-wall, 27.

Primrose, 103, 110.

Procambium (*pro*, before; cambium)—Outer part of the plerome originating the vascular bundles, 66.

Pro-embryo (*pro*, before; embryo), in Chara—The rudimentary sporophyte, 41.

Promycelium (*pro*, before; mycelium), in Mucor—The rudimentary sporophyte, 19.

Prosenchyma (πρὸς, beside; ἔγχυμα, something poured or put in. This word was formed on the model of "parenchyma," with little regard to derivation)—Tissue composed of elongated elements, united by their tapering ends, 44.

Prostrate—Lying on the ground, 77.

Protection, 121; Of seed, 118.

Proteids (Πρωτεὺς, a sea-god with remarkable power of changing his form)—Complex compounds of COH, with small amounts of S and P, 1, 5, 25, 83, 120.

Prothallus (πρὸ, before; θαλλὸς, a shoot), in the higher plants—The simple oophyte, 59, 64, 74, 104, 128; Male and female, 64, 74, 104, 128.

Protococcus (πρῶτος, first; κόκκος, a berry), 4, 23, 120, 121, 122, 123, 124, 126.

Protonema (πρῶτος, first; νῆμα, a thing spun, a thread), in the Moss—A filamentous structure developed from the asexual spore, and also from rhizoids, &c., in vegetative reproduction. New oophytes arise as lateral buds upon it, 47, 49.

Protophloem (πρῶτος, first; phloem)—The first formed part of the primary phloem, 54.

Protoplasm (πρῶτος, first; πλάσμα, that which has been formed)—An extremely complex substance, upon which life-manifestations depend, 1, 12, 25, 121, 127.

Protoxylem (πρῶτος, fruit; xylem)—The first-formed part of the primary xylem, 54, 66, 69, 80.

Pseudocarp (ψευδὴς, false; καρπὸς, fruit). *See* Fruit, spurious, 112, 115.

Pteris (πτερὶς, a species of fern). *See* Fern, 50.

Pubescent (*pubesco*, I grow downy)—Downy, 93.

Putrefaction, 14, 15.

Pyxidium (πυξίδιον, dim. of πυξὶς, a box)—A transversely dehiscing capsule, 117, 118.

Q

Quadrant, 63.

Quadrifoliate (*quattuor*, *quadr-*, four; *folium*, a leaf)—Palmate, with four leaflets, 89.

R

Rabbit, 6.

Raceme (*racemus*, a bunch or cluster of berries)—A racemose inflorescence, with elongated axis upon the sides of which stalked flowers are arranged, 95.

Racemose, in an inflorescence—With predominant main axis, 65, 94.

Rachis (ῥάχις, the spine, the backbone)—The main axis of an inflorescence, 94.

Radical (*radix*, a root)—Situated on an underground stem, or at the base of an ordinary stem, 84.

Radicle (*radicula*, dim. of *radix*, a root)—The root of an embryo, 71, 75, 92, 114, 120.

Rain, 25.

Ramentum (*ramentum*, what is grated or shaved off, a scale), in the Fern—A scaly trichome, 57.

Rays, medullary (*medulla*, the marrow or pith of bones)—Radial bands of ground-tissue in the stem. They are—(1) Primary, extending from pith to cortex, 66, 69, 81; (2) Secondary, extending only part way between pith and cortex, 69.

Receptacle, floral. *See* Torus, 97; For nectar, 102, 109.

Receptive spot, in the Fern—Clear part of the oosphere, at which the spermatozoid enters. *Comp.* Papilla, apical, 62.

Replum (*replum*, in architecture, a bolt for covering the joining of a folding door), in the siliqua—A placental outgrowth dividing the ovary into two compartments, 117.

Reproduction—The function of producing new individuals.

(1) *Vegetative*—By means of the ordinary cells of the plant-body, 124; Yeast, 13; Bacteria, 15; Mucor, 18; Protococcus, 26; Spirogyra, 28; Chara and Nitella, 40; Moss, 47; Fern, 62; Angiosperm, 108.

(2) *Asexual*—By means of special cells (spores), derived from a single organ, 124; Yeast, 13, 14; Bacteria, 15; Mucor, 18; Penicillium, 22; Protococcus, 26; Moss, 47; Fern, 62; Pinus, 75; Angiosperm, 108.

(3) *Sexual*—By spores formed of protoplasm from two organs, 124; Mucor, 19; Penicillium, 22; Spirogyra, 29; Fucus, 34; Chara and Nitella, 40; Moss, 48; Fern, 62; Pinus, 75; Angiosperm, 108.

Reproductive Organs—Those concerned with spore-reproduction.

(1.) *Asexual*—Producing asexual spores. Mucor, 17, 18; Penicillium, 20; Fern, 57; Pinus, 72; Angiosperm, 93.

(2.) *Sexual*—Producing gametes. Mucor, 18, 19; Penicillium, 21; Fucus, 33; Chara and Nitella, 38; Moss, 46; Fern, 59; Pinus, 74.

Reserve-materials—Substances formed from the food, and stored up for future use, 76, 83, 92, 107, 113, 120.

Resin—A complex waste-product, composed of C, O, and H, 83, 93.

Resin-passage—An intercellular canal, lined by cells which excrete resin into it, 69, 70, 71, 84.

Respiration—Excretion of CO_2 (and water), with concomitant intaking of O; Yeast, 13; Mucor, 18; Penicillium, 22; Protococcus, 26; Moss, 47; Fern, Pinus, and Angiosperm, 108.

Resting-spore—One which remains dormant for some time before commencing to develop, 30, 122.

Reticulate (*reticulum*, dim. of *rete*, a net)—Forming a network, 88.

Rhizoid (ῥίζα, a root; *εἶδος*, *ἰδ-*, appearance, likeness)—One of numerous filaments performing root-functions in lower plants, 127, 128; Chara and Nitella, 35, 37, 123; Moss, 44, 45, 48, 123.

Rhizome (ῥίζωμα, a root)—A creeping or underground stem, 50, 77, 107, 108.

Ribbed, 78.

Ring, in Ferns—The thickened margin of the sporangium, 58.

Ring, annual, 65, 70, 79; Cambium, 66, 72.

Robinia, 88.

Root. For definition *see p.* 57. Fern, 56, 123; Pinus, 71, 122, 123; Angiosperm, 92, 106, 112, 122, 123.

Root—Adventitious, not acropetally developed, 92; Aerial, adapted for absorbing water, &c., from the air, 92, 106; Fibrous, 92; Primary, developed from the radicle of the embryo, 41, 92; Secondary, 92; Sucker, piercing another plant and deriving nutriment from it, 92, 106; Tap, a well-developed primary root, 71, 92.

Root-cap—A sheath of cells covering the growing apex of a root, 56, 72, 92.

Root-hair—One of numerous delicate unicellular hairs usually found on roots, 57, 59, 63, 92, 106, 123.

Root-pressure—Extremely active absorption by the root, resulting in filtration of liquid under pressure into the vessels, 107.

Rose, 86, 99, 103, 115, 123.

Rostellum (*rostellum*, dim. of *rostrum*, a beak), in Orchids—A modified stigma, subserving attachment of the pollinia to an insect, 110.

Rotation—Regular movement of a layer of protoplasm, 40, 127.

Runner—A creeping stem which produces adventitious roots, 108.

S

Saccharomyces (σάκχαρον, a kind of sugar; μύκης, a mushroom). *See* Yeast, 11.

Sagittate (*sagitta*, an arrow)—Arrow-shaped, 90.

Salts, simple, 5; inorganic, 25, 123.

Salvia, 99, 100.

Samara (*samara*, the seed of the elm)—A winged mericarp, 116.

Scale—A flattened structure, 93; Ovuliferous, in Pinus—The flattened, largely developed placenta, 74.

Scarlet runner, 79, 120.

Scattered—Growing out singly from the nodes, 85.

Scent, 109, 125.

Sclerenchyma (σκληρὸς, hard; ἔγχυμα, anything poured or put in)—Tissue composed of elements with thickened and lignified cell-walls, but no protoplasm, 52, 55, 57, 70, 71, 80, 83, 91, 107, 108, 116, 122.

Sclerotium (σκληρόω, I harden)—in Fungi, a hardened fruit, capable of remaining dormant for some time, 122.

Scolopendrium, 58.

Scorzonera, 95.

Scutellum (dim. of *scutum*, a shield)—The shield-shaped cotyledon of Grasses, 120.

Secondary—Not formed from the first. *See* Root, Phloem, and Xylem.

Sections—Radial and tangential, 69.

Seed, in Phanerogams—The developed macrosporangium (ovule), containing the dormant sporophyte-embryo; Pinus, 75; Angiosperm, 107, 108, 112, 114, 120, 125.

Seed, Dispersion, 119; Protection, 118; Throwing, 119.

Seed-coat—Covering of the seed, 75, 113, 120.

Segmentation, in *Spirogyra*—A method of vegetative reproduction by separation of the constituent cells, 29.

Selaginella, 64.

Self-fertilization, in a *bisexual flower*—Fertilization by its own pollen, 40, 125.

Self-sowing—The production of specially modified fruits near the ground, into which they grow to set their seeds, 119.

Self-sterile, in a *bisexual flower*—Incapable of being fertilized by its own pollen, 111.

Sensitiveness, 4.

Sensitive Plant, 4, 111, 127.

Sepal (*sepalum*, a leaf)—One of the leaves of the calyx, 97, 102.

Sepaloid (*sepalum*, a leaf; εἶδος, ἰδ-, appearance, likeness)—Like a sepal, 98.

Septicidal (*sæptum*, *septum*, a partition-wall; *cædo*, *cid-*, cut)—Of a *capsule*, with the dissepiments splitting in dehiscence, 117.

Septifragal (*sæptum*, *septum*, a partition-wall; *frango*, *frag-*, break)—Of a *capsule*, with the side-walls splitting away from the dissepiments in dehiscence, 117.

Serrated (*serra*, a saw)—Notched like a saw, 30, 89.

Sessile (*sessilis*, sitting; *sedeo*, *sessum*, sit)—Stalkless, 44, 86, 101.

Seta (*sæta*, *seta*, a bristle), in the Moss—The stalk of the sporogonium.

Sexual Generation. *See* Oophyte.

Shape, of stems, 77; of leaves, 89; of flowers, 98, 125.

Sheath, in some leaves—The part which more or less enwraps the stem, 86.

Shepherd's Purse, 113.

Shield, in Chara—One of the eight plates forming the wall of the antheridium, 39.

Shoot—A stem with its leaves, 35.

Shrub—A small woody plant, 76.

Sieve-plates—Perforated areas occurring in the walls of sieve tubes, by which (1) the members of the same tube and (2) different tubes communicate, 54, 69, 80.

Sieve-tube—A tube with protoplasmic lining and cellulose walls, composed of elongated cells placed end to end and communicating by sieve-plates, 54, 66, 69, 80, 107.

Siliqua (*siliqua*, a pod or husk)—A dry, longitudinally dehiscent fruit, composed of two carpels, and with the ovary divided into two by a placental outgrowth. *See* Plum, 117.

Silky, 93.

Simple—Not divided into leaflets, 87.

Sloe, 98.

Snapdragon, 118.

Soil, 106.

Sorus (σωρὸς, a heap)—An aggregation of sporangia, 57.

Spadix (σπάδιξ, a twig)—A racemose inflorescence, possessing an elongated, thickened axis with sessile flowers, and enclosed in a spathe, 95.

Spathe (σπάθη, the sheath of the male palm)—A large bract, ensheathing a spadix, 95.

Species, 7.

Spermatozoid (σπέρμα, σπέρματος, a seed; ζῷον, a living creature; εἶδος, ἰδ-, appearance, likeness)—A motile male gamete, provided with two or more flagella, 4, 124, 116, 128 (= antherozoid, ἄνθος, a blossom; ζῷον, a living creature; εἶδος, ἰδ-, appearance, likeness); Fucus, 33; Chara and Nitella, 39; Moss, 46, 48; Fern, 50, 62; Selaginella, 64; [Pinus, 74; Angiosperm, 105.]

Spermatozoid-mother-cell—A cell which produces a spermatozoid, 46, 60.

Spike—A racemose inflorescence, with elongated unthickened axis and sessile flowers, 95.

Spine—A sharp-pointed protective body formed by modification of a branch or part of a leaf, 78, 90, 123.

Spiral, 97.

Spirillum (dim. of σπεῖρα, *spira*, a coil), 14, 15.

Spirogyra (σπεῖρα, *spira*, a coil; γῦρος, a circle, a ring), 26, 121, 122, 123, 124, 127.

Split-fruit—A dry, indehiscent, two or more-seeded fruit, separating when ripe into one-seeded mericarps, 116.

Spontaneity—The function by which movements, &c., are produced as the result of internal causes, without the direct action of external stimuli, 127; Protococcus, 26; Fucus, 34; Chara and Nitella, 41; Moss, 49; Fern, 62; Angiosperm, 111.

Spontaneous Generation (Abiogenesis)—Derivation of living from non-living matter, 3, 15, 16.

Sporangium (σπορὰ, seed; ἀγγεῖον, a vessel)—A case containing asexual spores, 17, 18, 19, 57, 58, 122, 124.

Spore (σπορὰ, seed) — A special reproductive cell, which is either (1) asexual, derived from a single organ, or (2) sexual, formed by the fusion of two gametes, 15, 18, 44, 59, 62, 63, 124, 128.

Spore-sac, in the Moss—Layers of parenchyma which enclose the sporogenous layer, 43.

Sporogenous layer (σπορὰ, seed; γεννάω, I produce), in the Moss—Spore-producing layer, 43.

Sporogonium (σπορὰ, seed; γονὴ, birth, production), in the Moss—The sporophyte, 42, 49.

Sporophyll (σπορὰ, seed; φύλλον, a leaf)—A spore-bearing leaf, 72, 93, 97, 99; Male, producing microspores, 73, 99; Female, producing macrospores, 73, 99, 100.

Sporophyte (σπορὰ, seed; φυτὸν, a plant)—The asexual generation; Table, 126, 128; Mucor, 20; Penicillium, 23, 122; Chara and Nitella, 41; Moss, 42, 47, 49; Fern, 50, 62, 125; Pinus, 64, 75, 125; Angiosperm, 76, 108, 112, 125.

Spur—A tubular receptacle for nectar, 102, 110.

Spurge, 83.

Spurious Fruit. *See* Fruit, Spurious.

Stalk—(1) an herbaceous stem; (2) the narrow supporting part of leaves, &c., 77.

Stamen (*stamen*, a thread), in Phanerogams—The male sporophyll, 73, 99, 102, 103, 108, 109.

Standard, in a papilionaceous flower—The posterior petal, 98.
Starch, 5, 25, 83, 107, 112, 120, 123.
Starch-star, in Chara—A detachable underground node, crammed with starch, and possessing numerous whorls of short leaves, 40.
Stationary Stage (Protococcus), 23.
Stem (for definition *see* p. 35)—127, 128; Moss, 44; Fern, 50; Pinus, 64; Angiosperm, 77.
Stem, Aquatic, 81, 84; Anomalous, 81.
Stigma (στίγμα, a mark), in Angiosperms—Receptive surface of the gynœcium, 101, 102, 109, 110, 128.
Stimulus, 26.
Stipule (*stipula*, a stalk, a blade)—Appendages of various shapes, situated at the origin of a leaf, 86, 87.
Stoma (στόμα, a mouth)—A cleft in the epidermis, bounded by special cells (guard cells), and placing the internal tissue in communication with exterior, 43, 56, 71, 79, 81, 91, 107; Water, a stoma with immovable guard-cells, usually situated over a water-gland, 92.
Stonecrop, 90, 92.
Stone-fruit. *See* Drupe, 118.
Straight, in the ovule—In the same straight line as the funicle, 101, 103, 115, (= orthotropous, ὀρθὸς, straight, upright; τροπὴ, a turning).
Strawberry, 115.
Streaming—The occurrence of numerous currents in protoplasm, which take various directions that often alter, 28, 127.
Struggle for Existence, 6.
Strychnine, 108.
Style (στῦλος, a pillar)—The (usually) narrow upper part of a carpel or gynœcium, on which the stigma is usually borne, 101, 102, 110.
Stylogonidium (στῦλος, a pillar; gonidium)—A gonidium pinched off from the end of a gonidiophore, 21, 22, 124.
Suborbicular (*sub*, diminutive; *orbiculus*, dim. of *orbis*, a circle)—Somewhat circular, 89.
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